US005648050A

United States Patent [19]

Matsumoto et al.

[11] **Patent Number: 5,648,050**

[45] **Date of Patent: *Jul. 15, 1997**

[54] **METAL CARRIER**

[75] Inventors: **Toshiki Matsumoto**, Kariya; **Tetsuya Toyao**, Toyoake; **Tetsuya Nakamura**, Chiryu; **Shigeru Maehara**, Kariya; **Hiromasa Aoki**, Nagoya; **Tatsuya Fujita**; **Senta Tojo**, both of Kariya; **Kinji Hodaira**, Okazaki; **Takeshi Matsui**, Toyohashi; **Yushi Fukuda**, Chita-gun, all of Japan

[73] Assignee: **Nippondenso Co., Ltd.**, Japan

[*] Notice: The term of this patent shall not extend beyond the expiration date of Pat. No. 5,599,509.

[21] Appl. No.: **213,806**

[22] Filed: **Mar. 16, 1994**

[30] **Foreign Application Priority Data**

Mar. 17, 1993	[JP]	Japan	5-56908
Dec. 24, 1993	[JP]	Japan	5-350447

[51] **Int. Cl.^{6}** **F01N 3/28**; B01J 35/02

[52] **U.S. Cl.** **422/180**; 422/169; 422/170; 422/177; 422/179; 502/439; 502/527; 60/299

[58] **Field of Search** 422/179, 180, 422/177, 169, 170; 502/439, 527; 60/299; 428/593

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92/13635	8/1992	WIPO .

Primary Examiner—Robert J. Warden
Assistant Examiner—Hien Tran
Attorney, Agent, or Firm—Cushman Darby & Cushman Intellectual Property Group of Pillsbury Madison & Sutro, LLP

[57] **ABSTRACT**

It is the primary object of the present invention to provide a catalyst converter which can hold a sufficient amount of catalyst to raise the temperature thereof to the catalyst activation temperature in a short time without enlarging the metal carrier itself. The metal carrier **1** is arranged in the course of an exhaust manifold **3** of an engine **2** and is composed of an alternating winding of a flat sheet **7** and a corrugated sheet **8**, wherein slit parts **9** are formed in the flat sheet **7** and the corrugated sheet **8** of the metal carrier **1** in an end portion thereof, on the side the engine **2**.

12 Claims, 48 Drawing Sheets

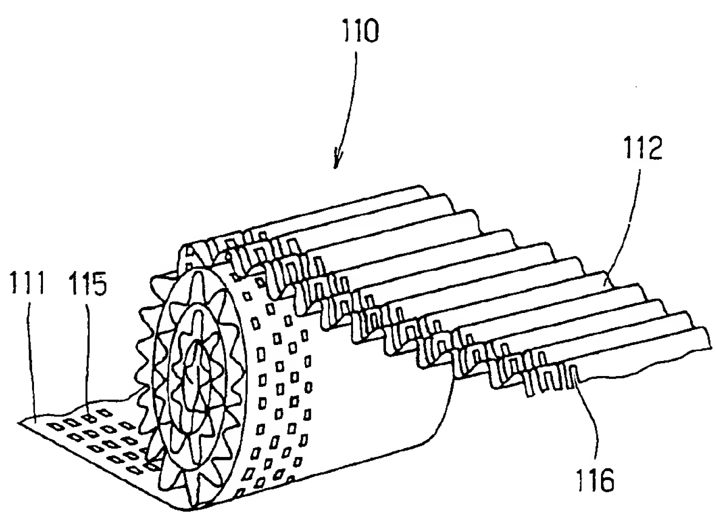


FIG. 1

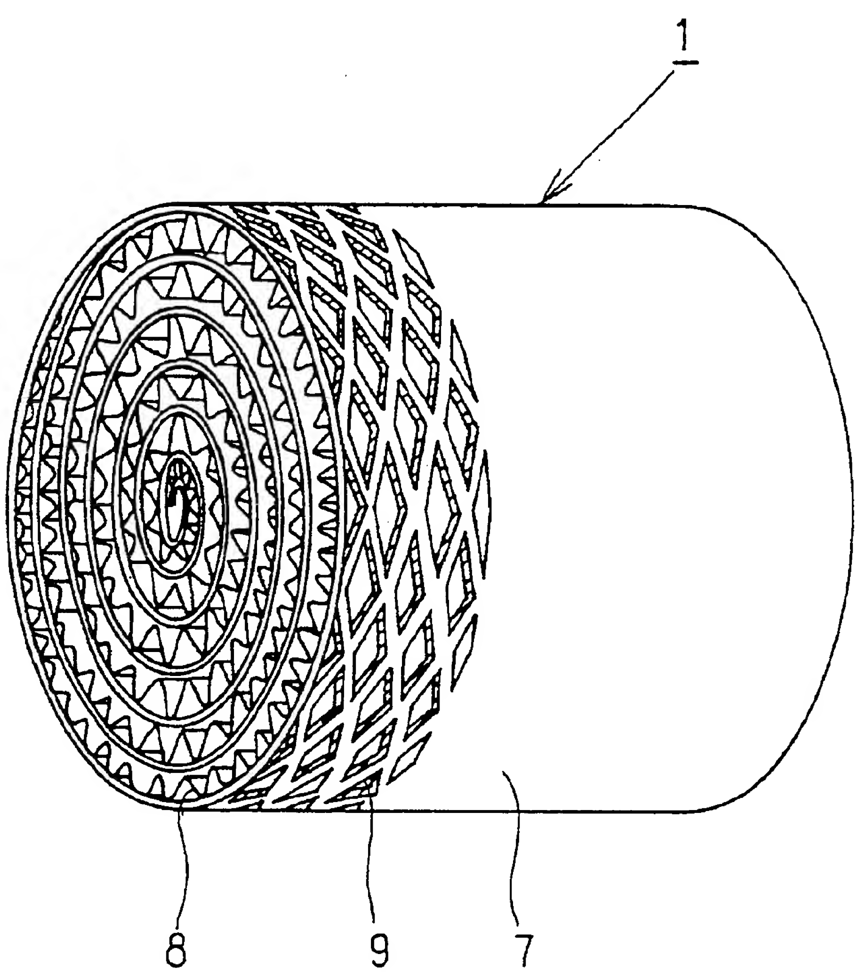


FIG. 2

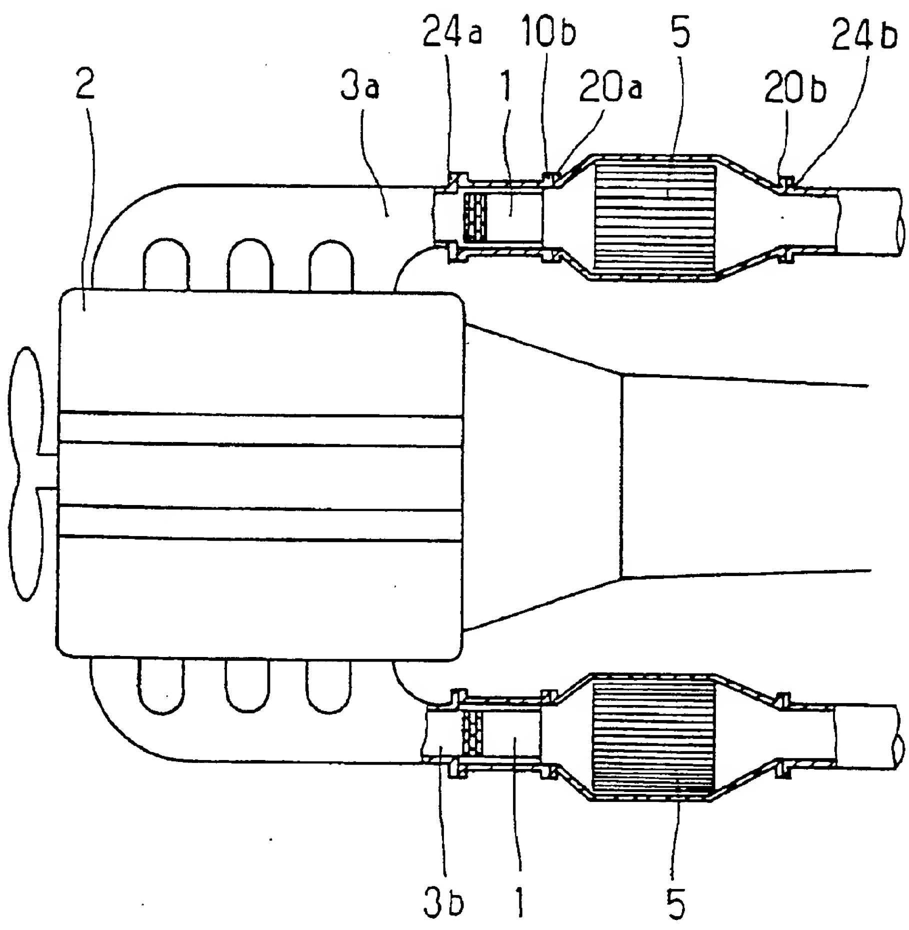


FIG. 3

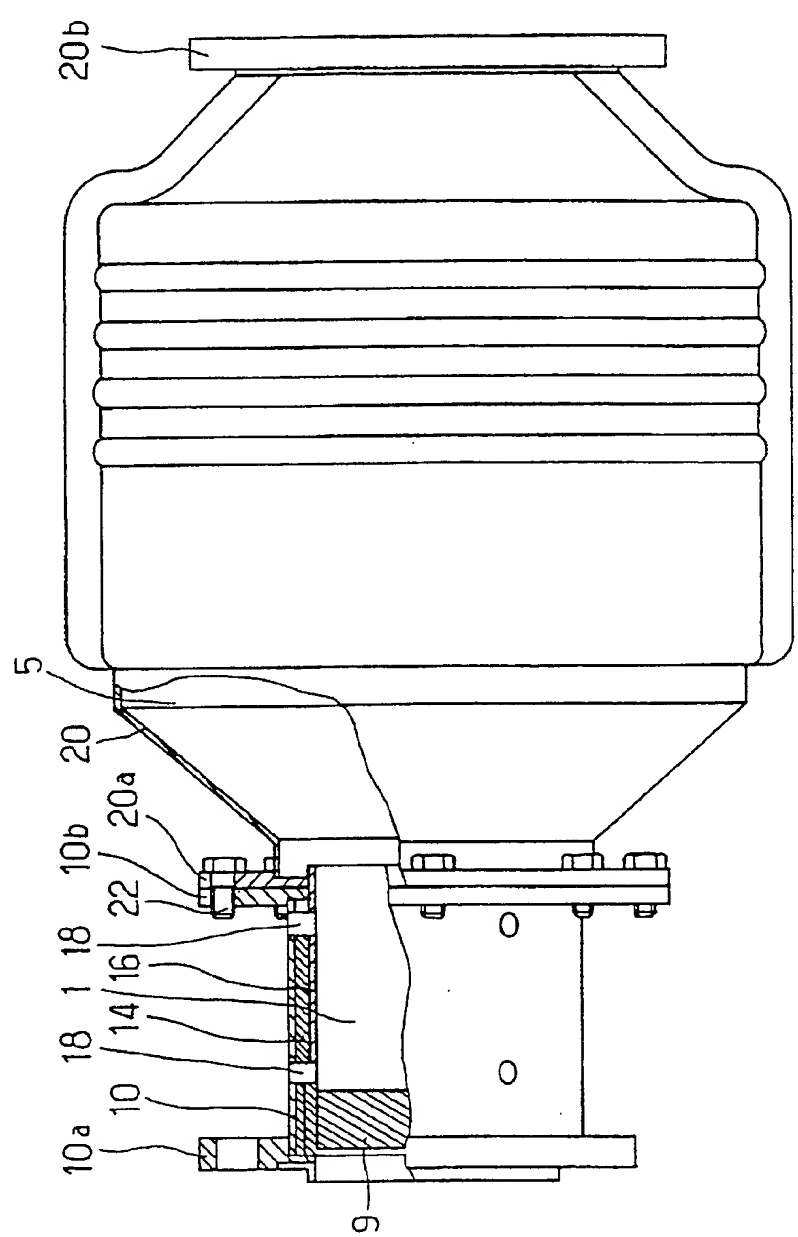


FIG. 4

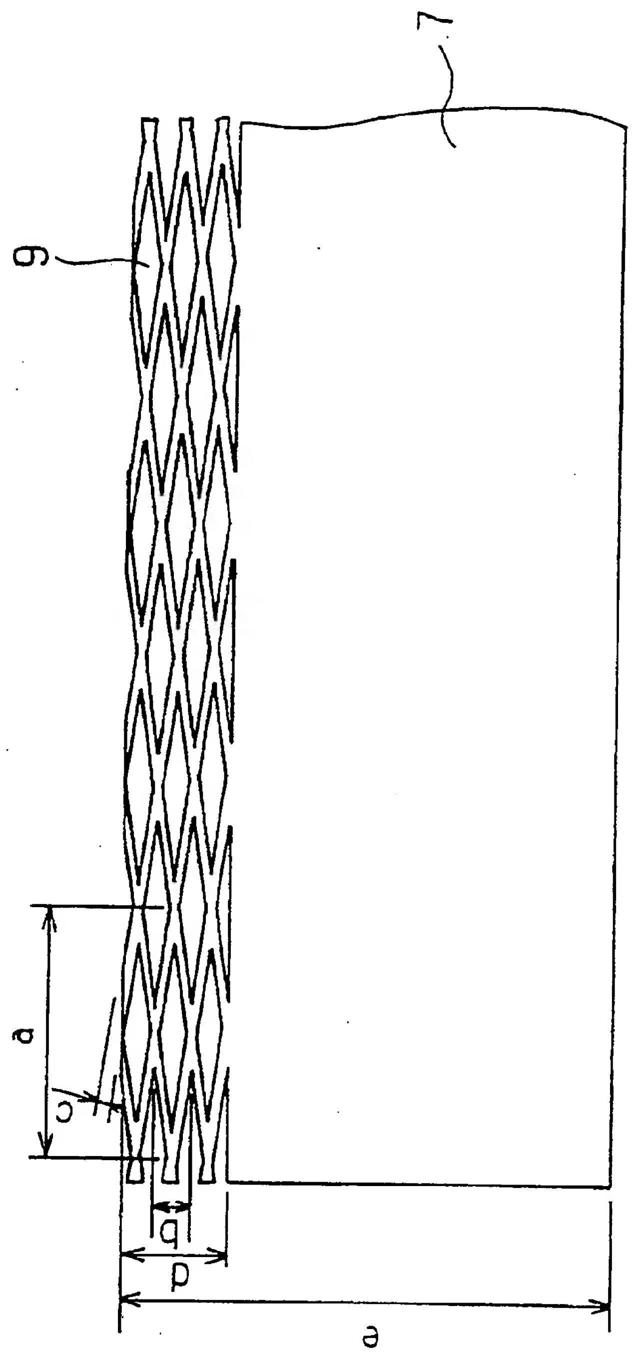


FIG.5

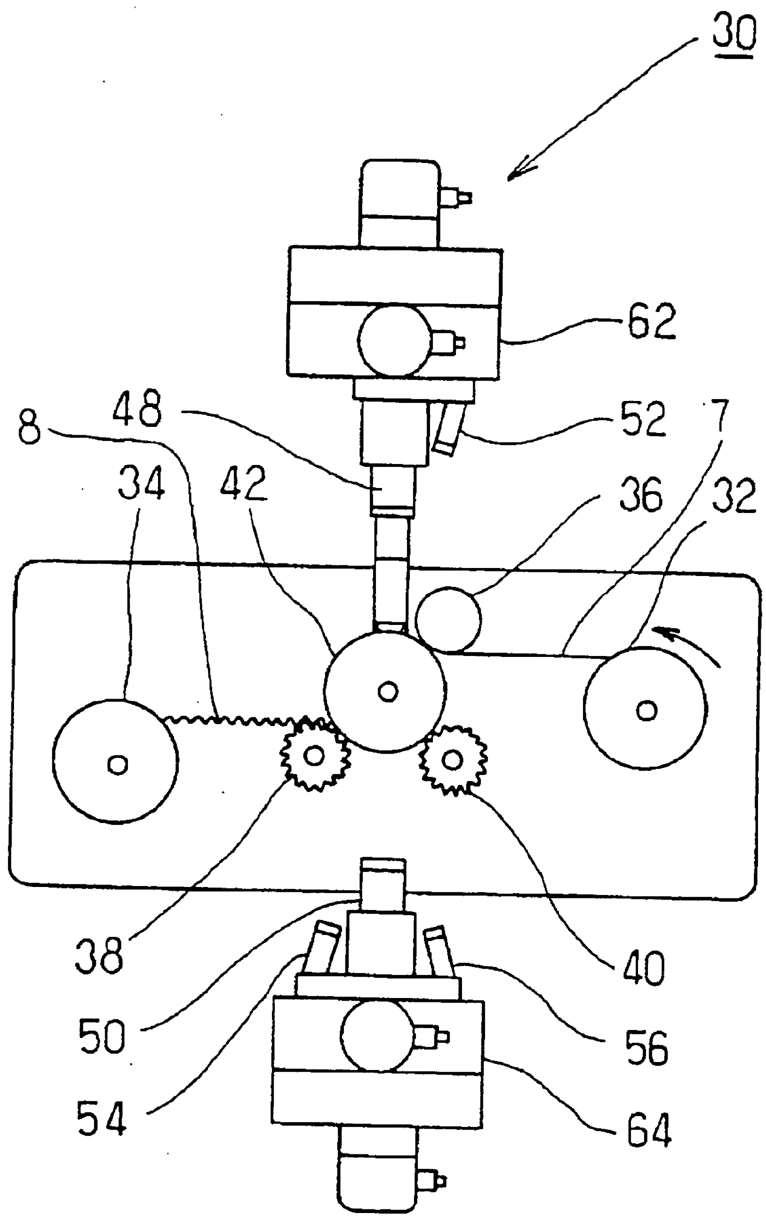


FIG. 6

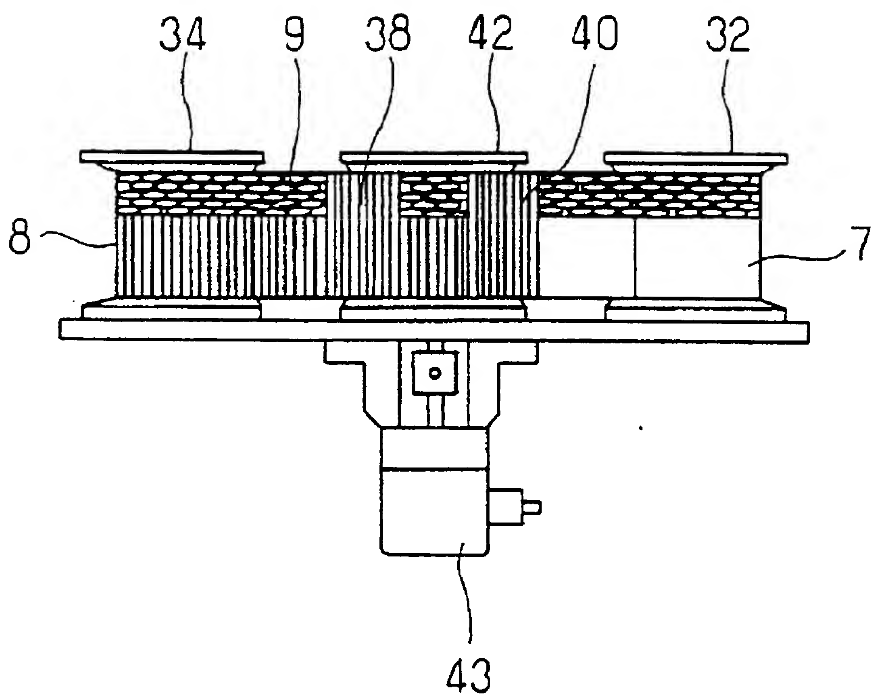


FIG. 7

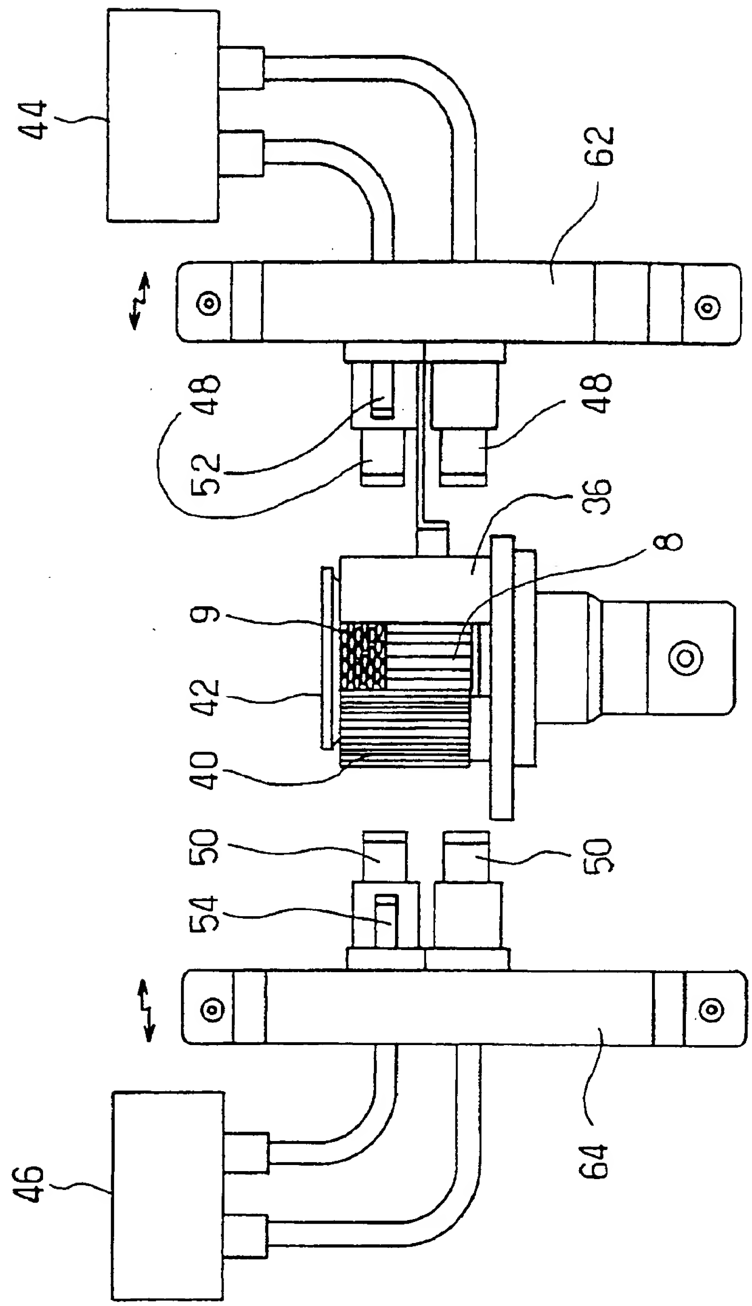


FIG.8

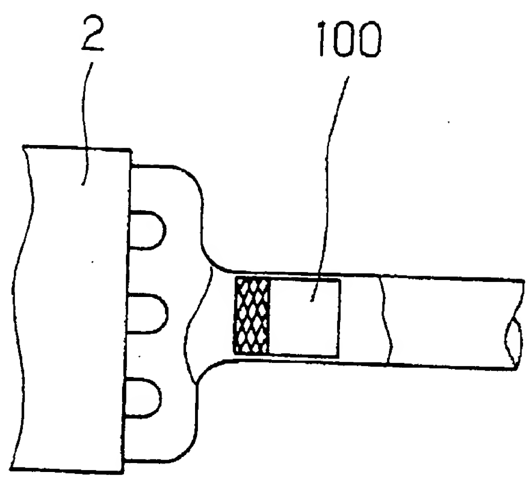


FIG. 9A

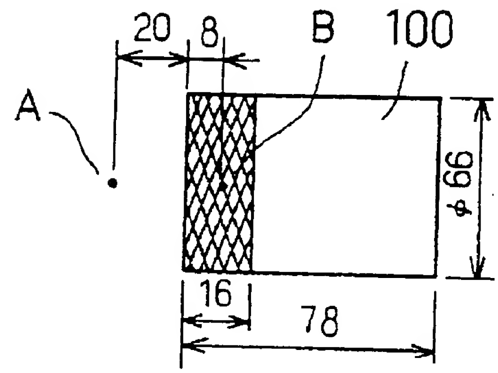


FIG. 9B

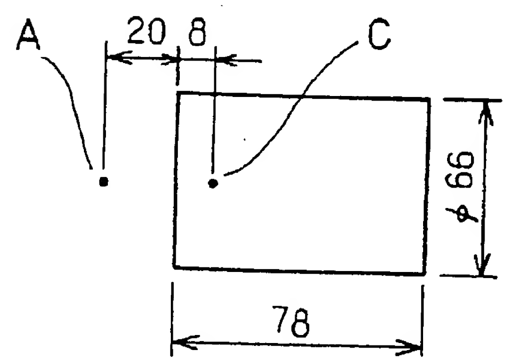


FIG.10

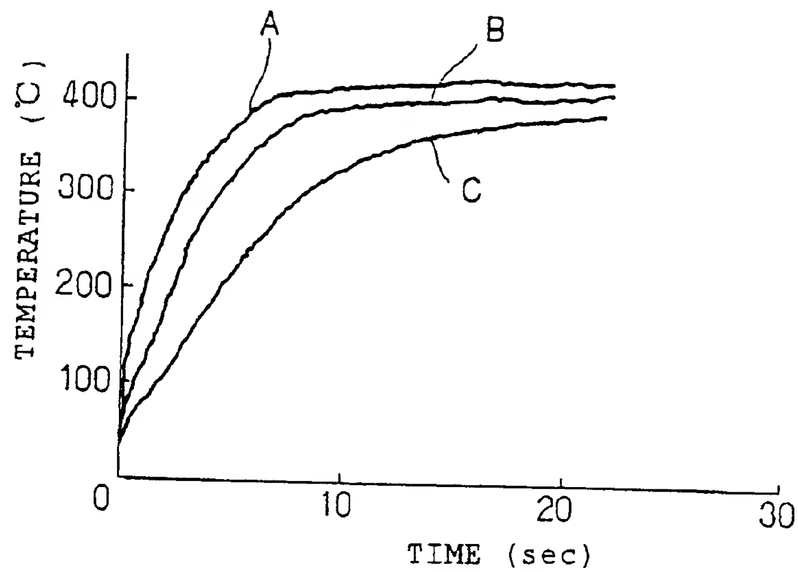


FIG.11

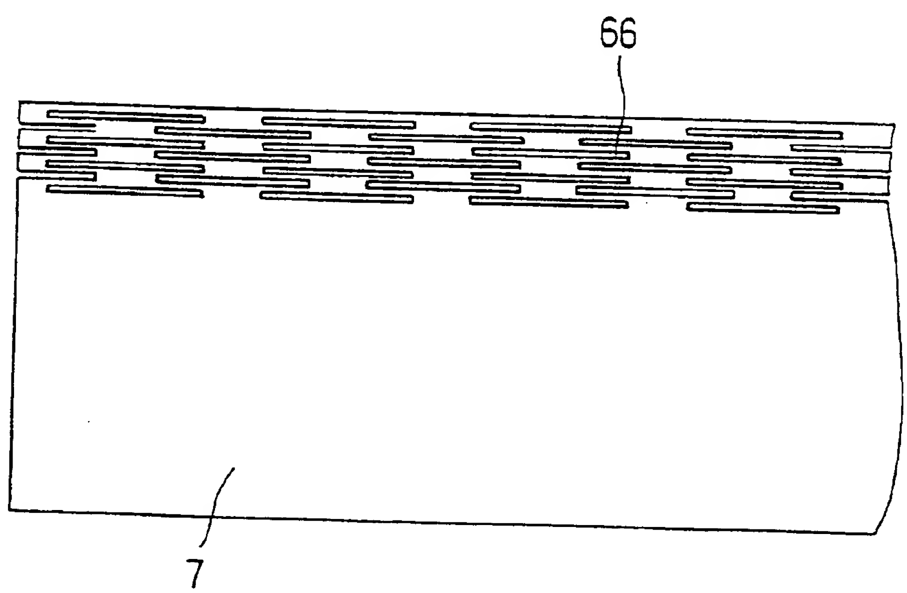


FIG.12

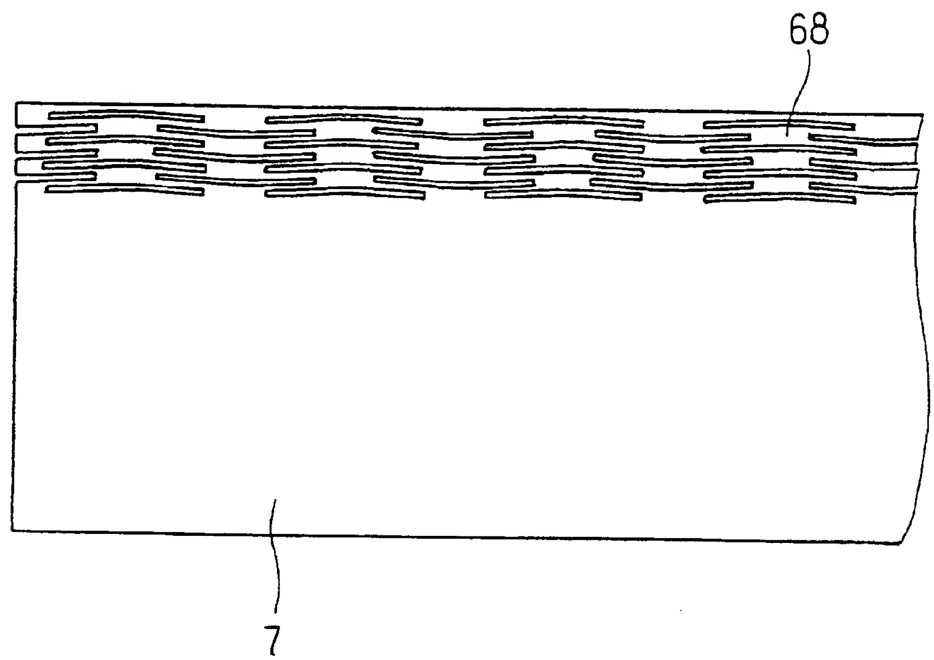


FIG.13

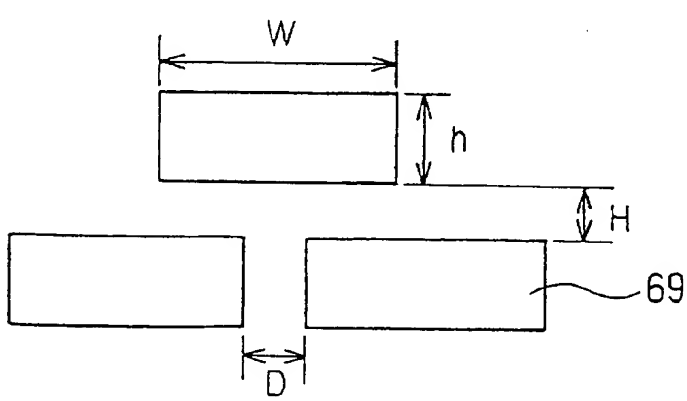
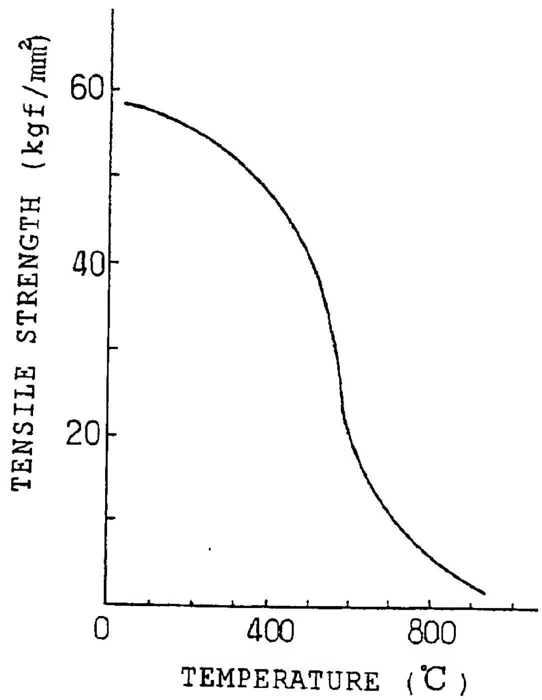
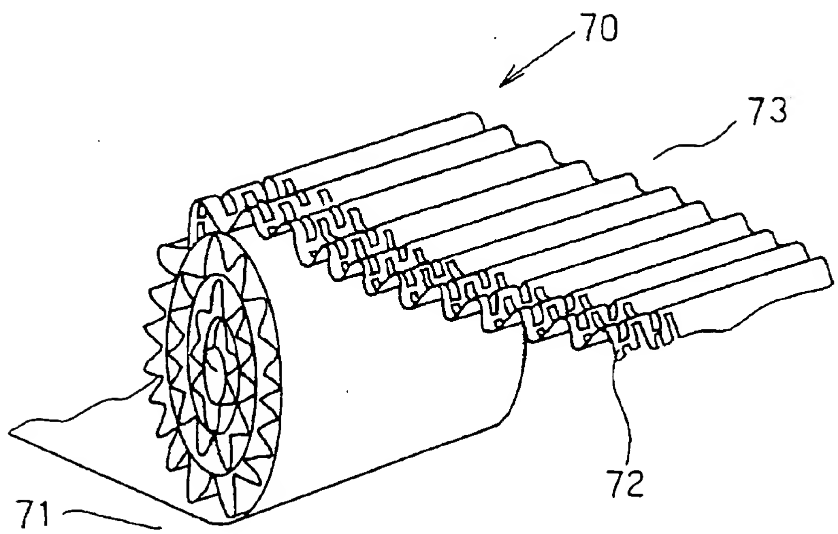


FIG. 14



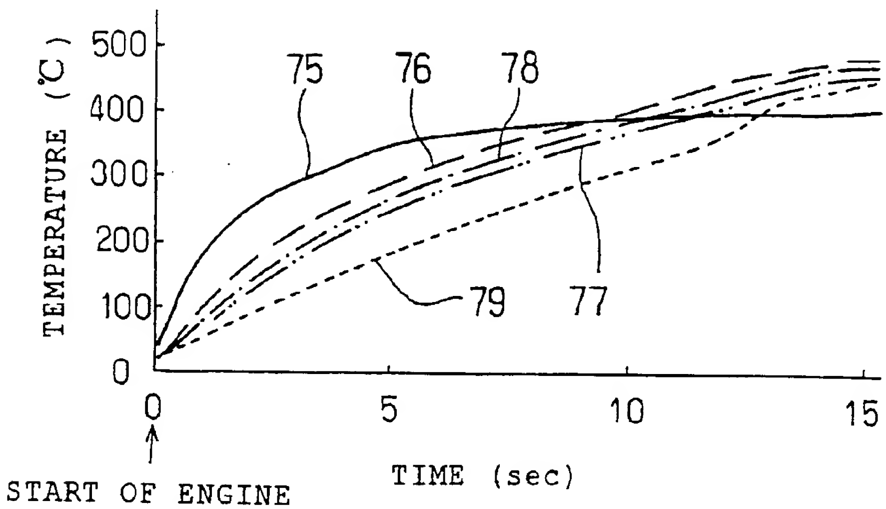
TENSILE STRENGTH (kgf/mm²)
60
40
20
0
400
800
TEMPERATURE (℃)

FIG. 15



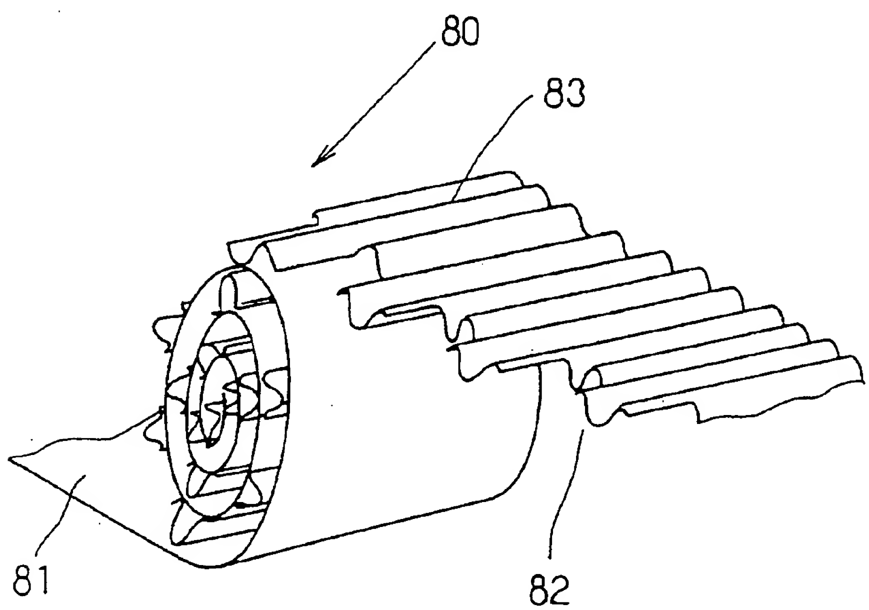
70
73
72
71

FIG. 16



TEMPERATURE (℃)
500
400
300
200
100
0
75
76
78
79
77
0
5
10
15
START OF ENGINE
TIME (sec)

FIG. 17



80
83
81
82

FIG.18

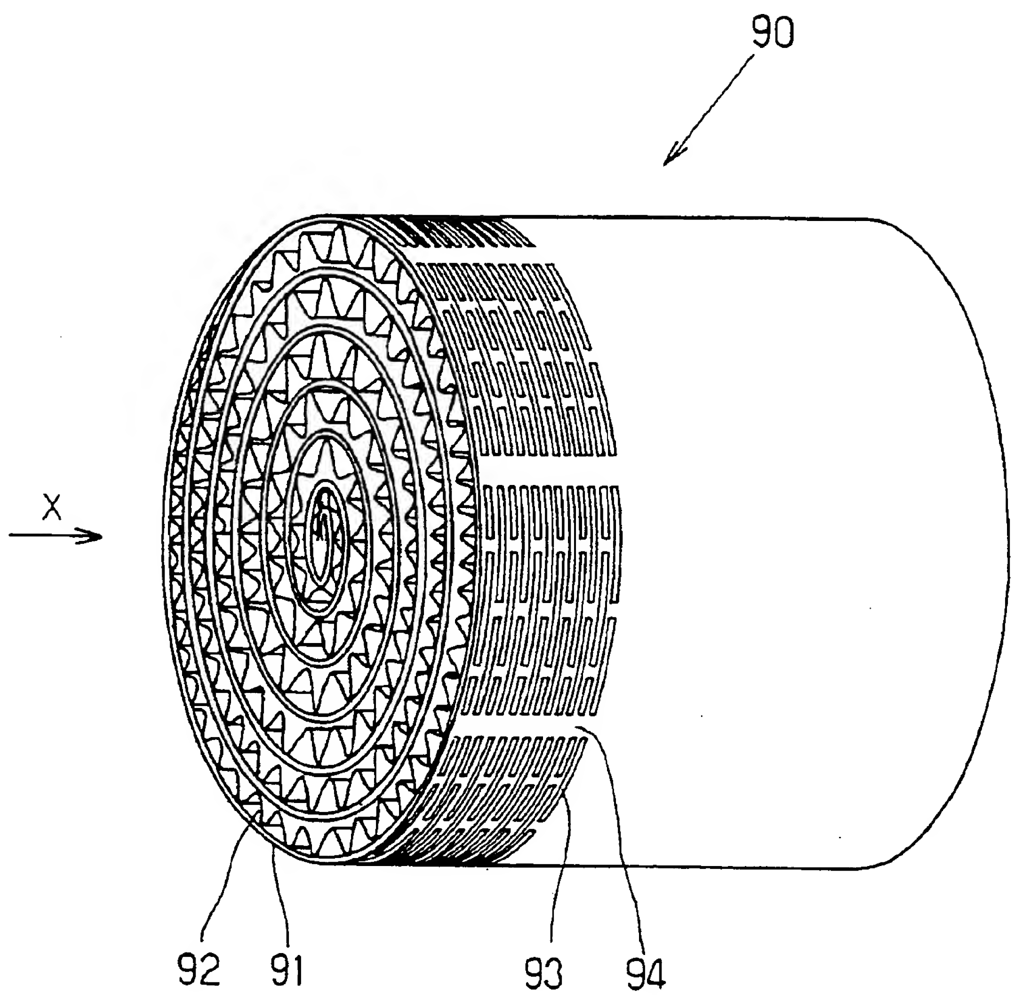


FIG. 19

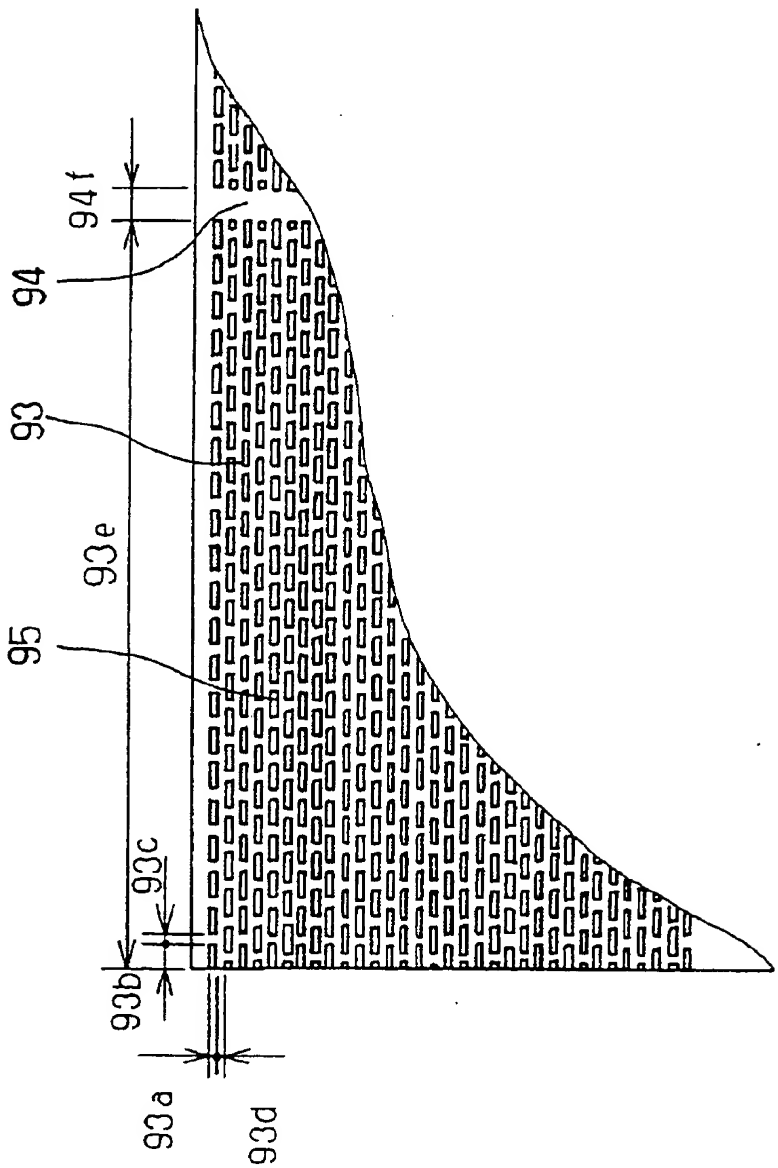


FIG.20

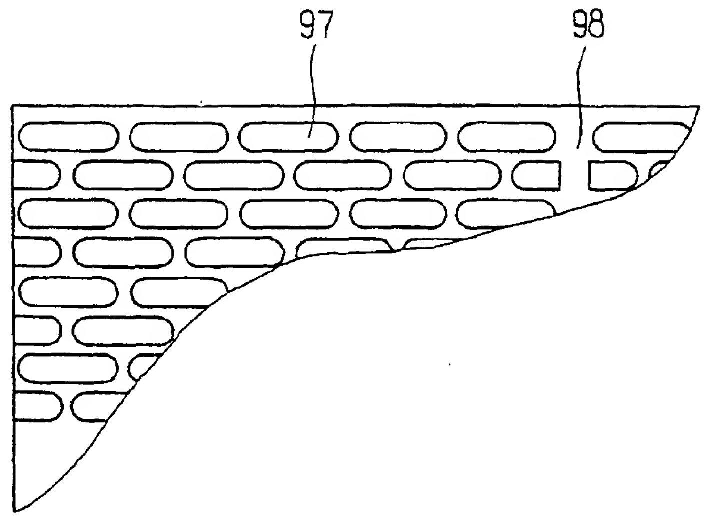


FIG.21

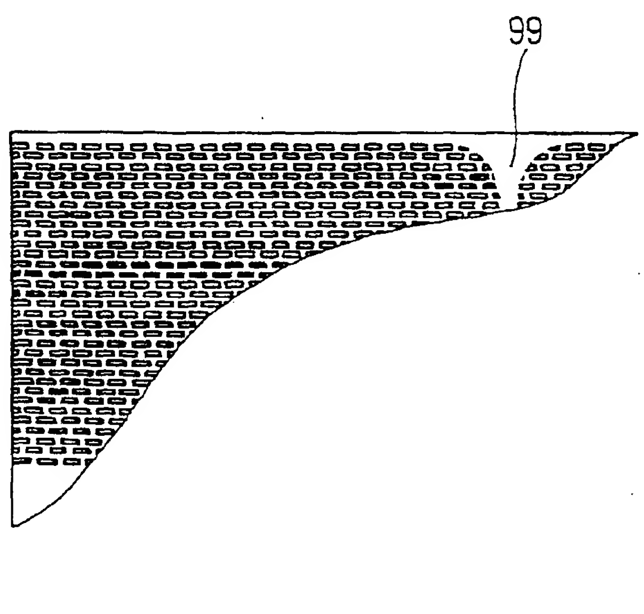


FIG.22

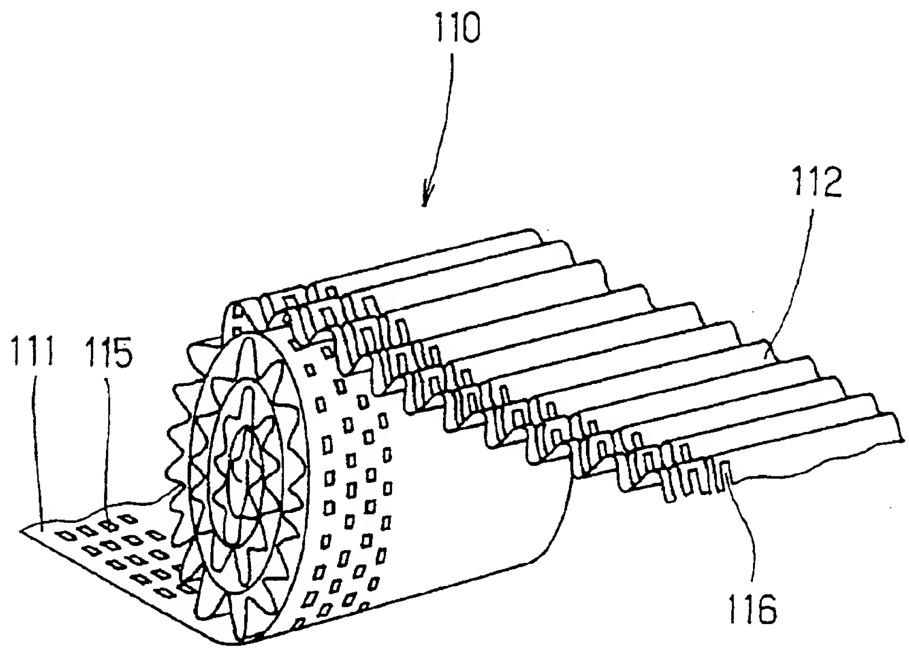


FIG.23

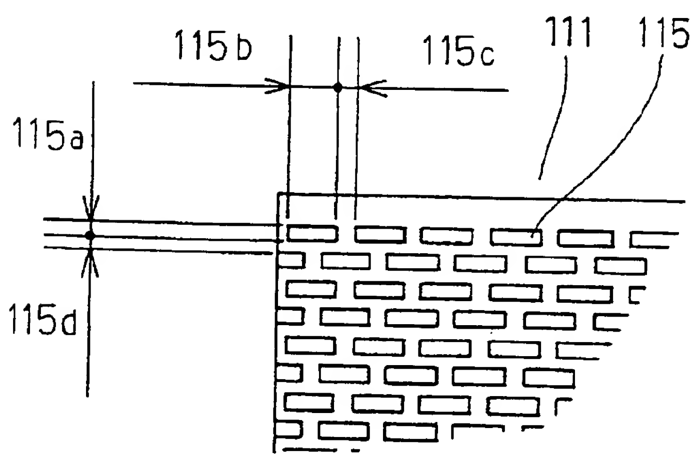


FIG. 24

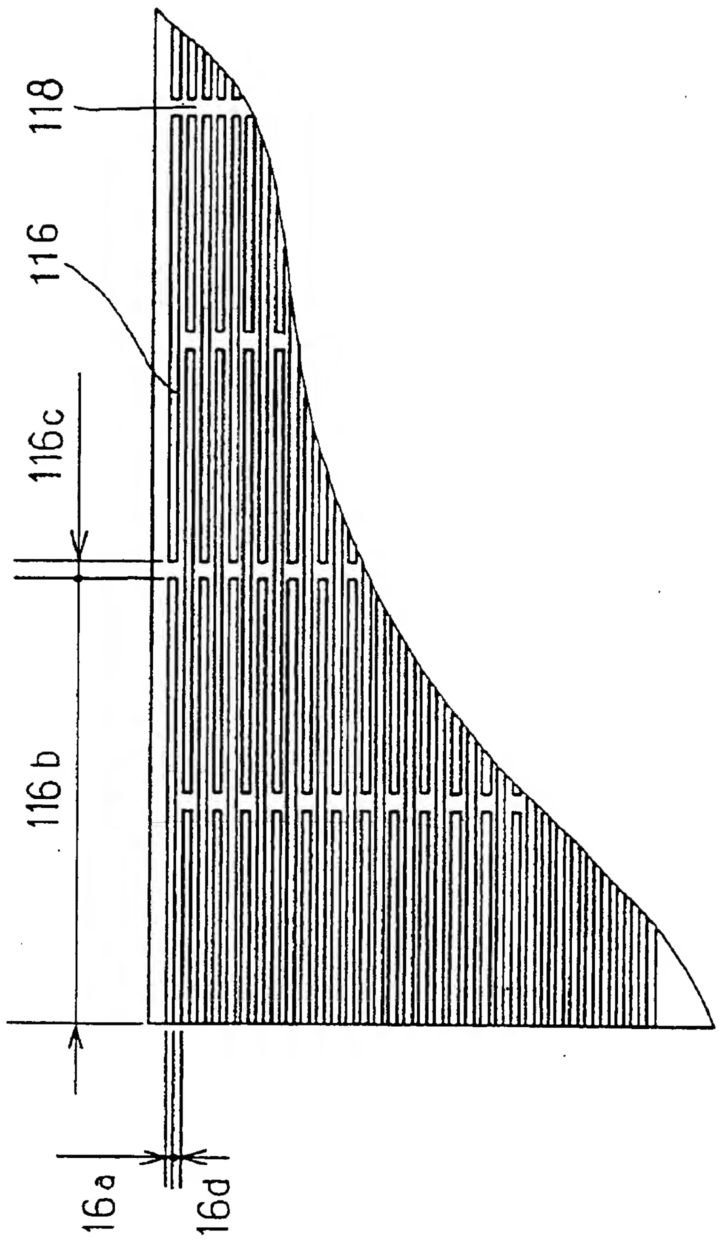


FIG. 25

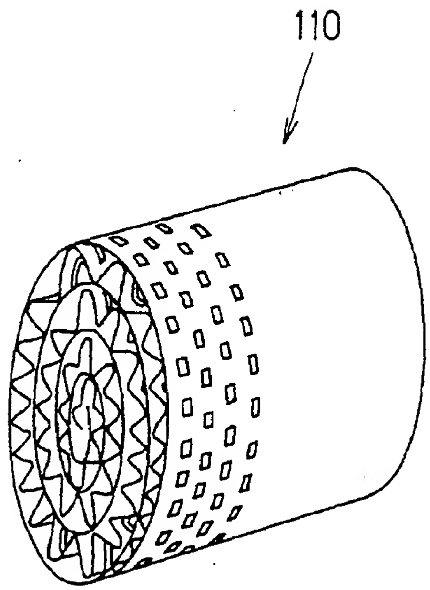


FIG. 26

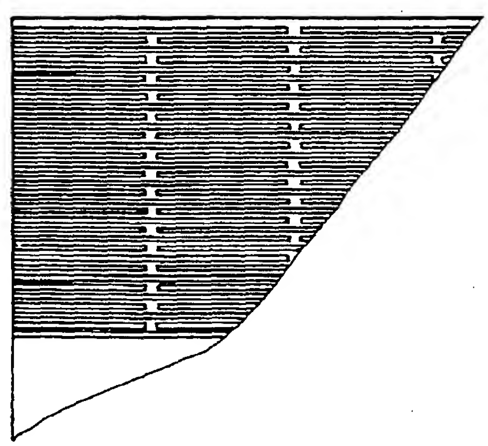


FIG.27

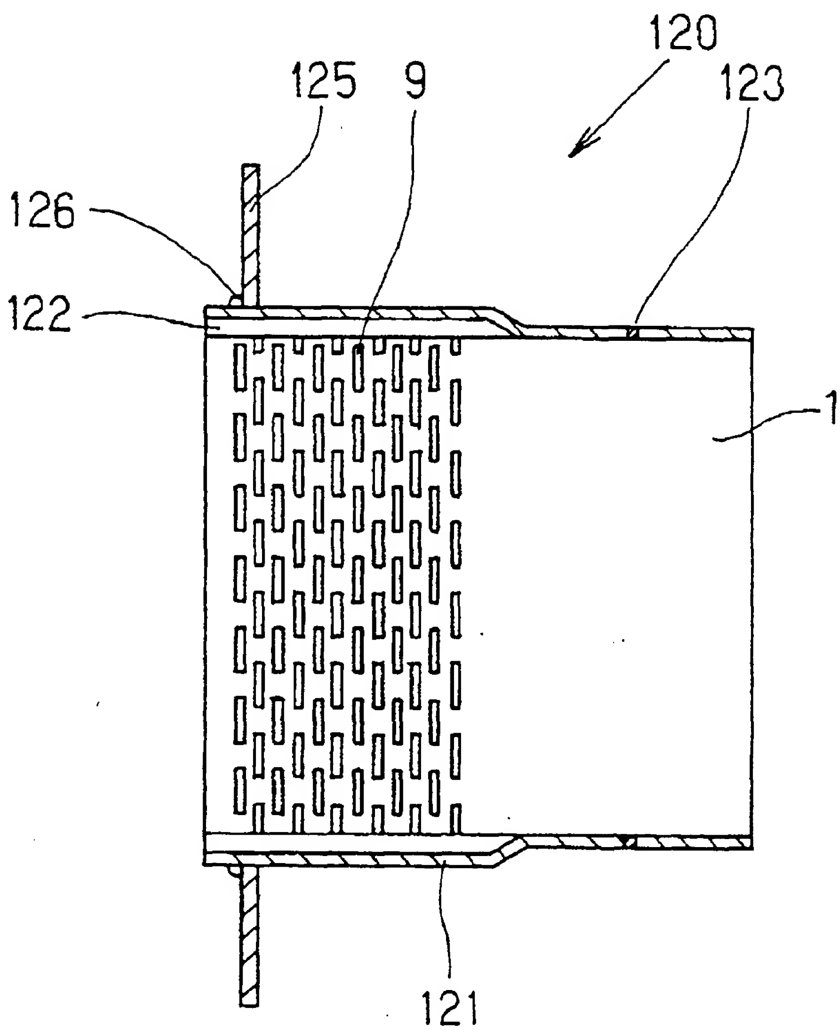


FIG. 28

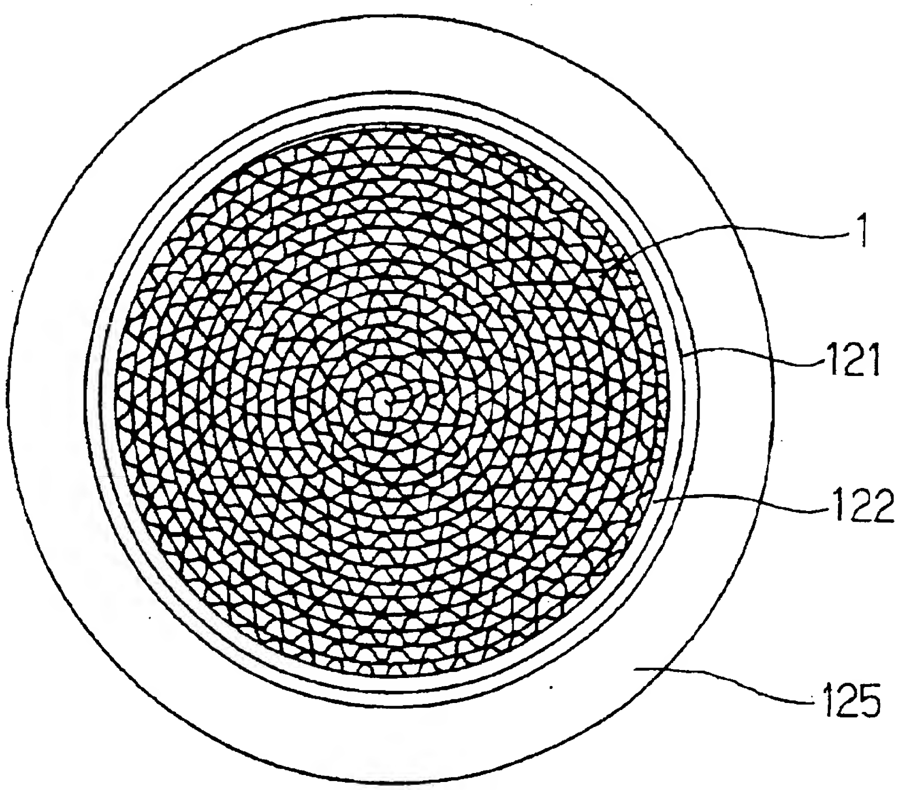


FIG. 29

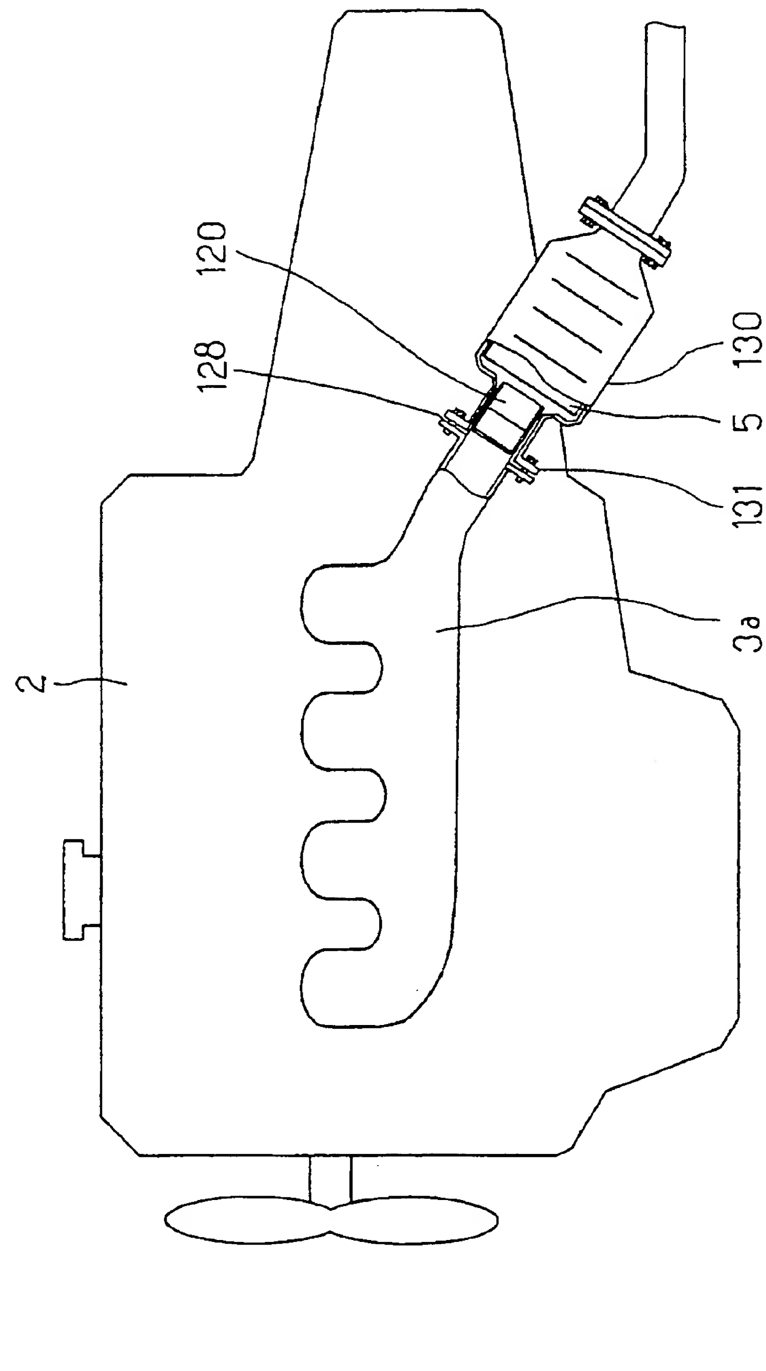


FIG. 30

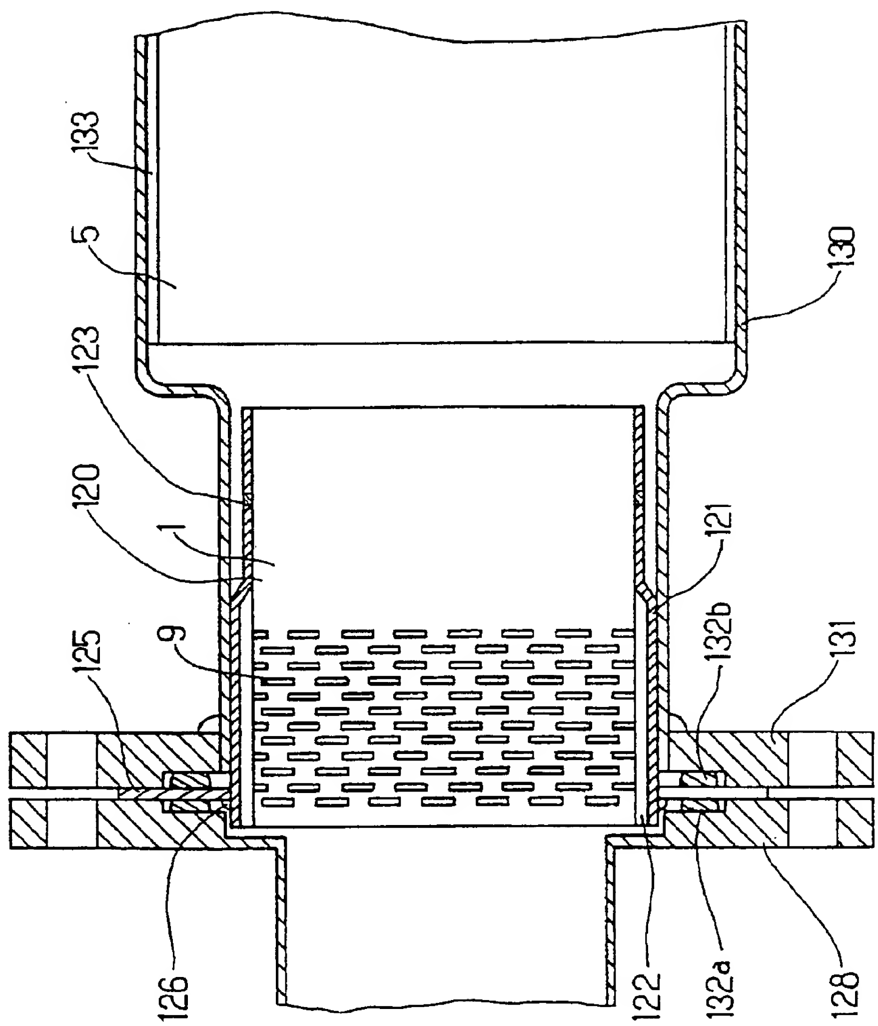


FIG. 31

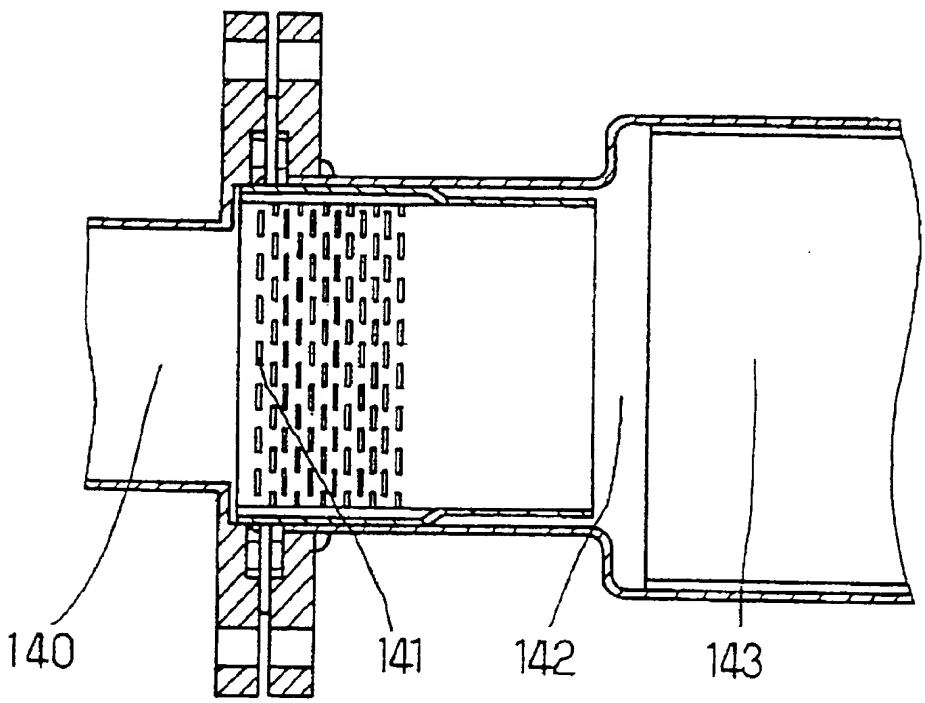


FIG. 32

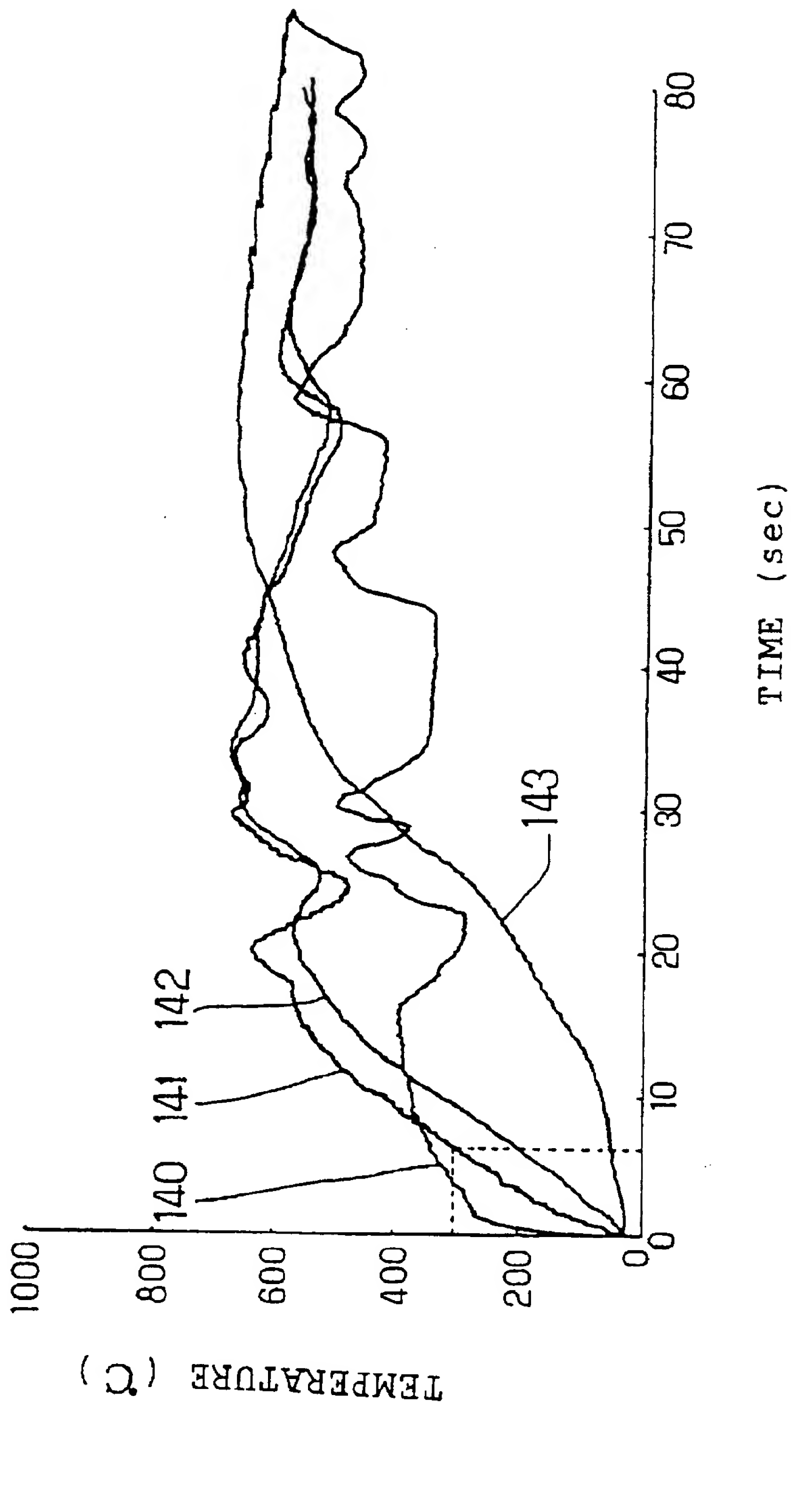

140
141
142
143
1000
800
600
400
200
0
0
10
20
30
40
50
60
70
80
TIME (sec)
TEMPERATURE (℃)

FIG. 33

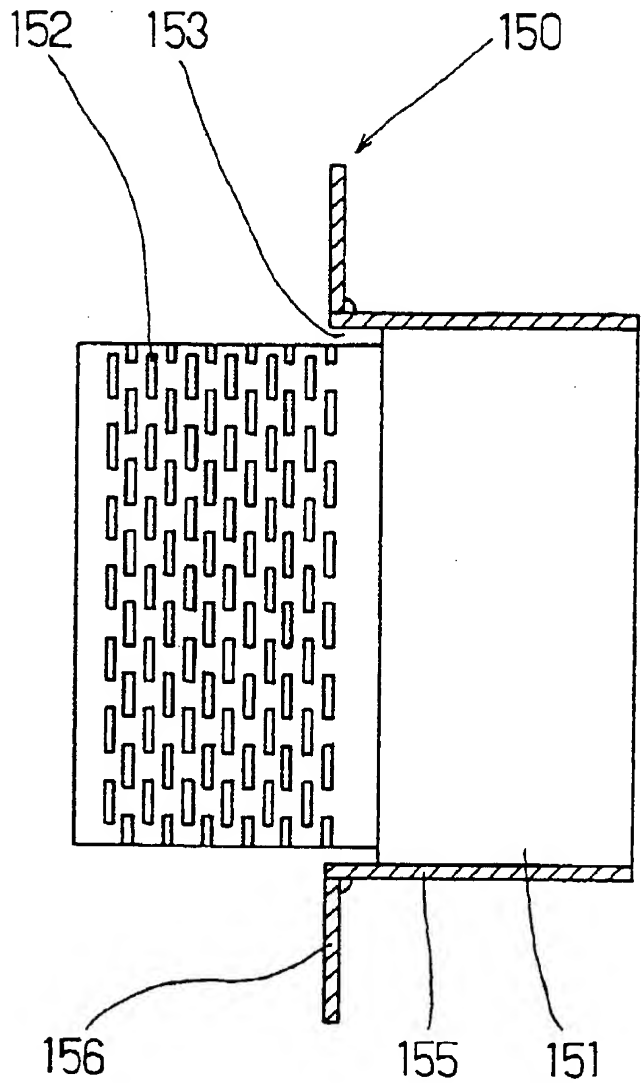


FIG. 34

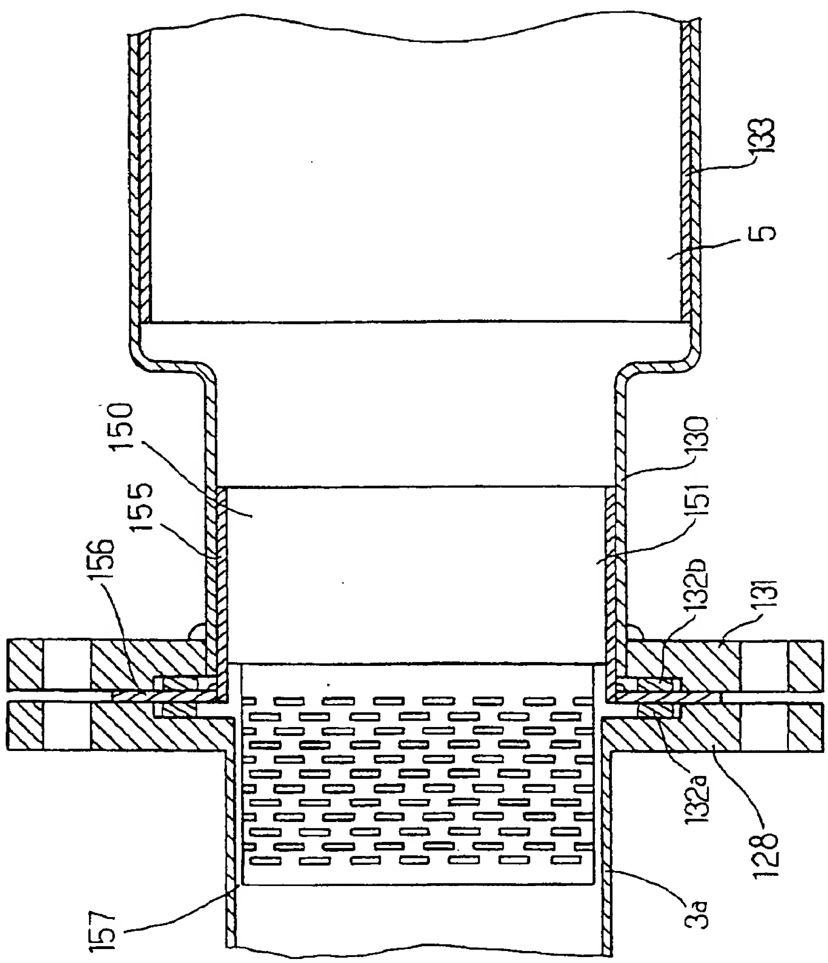


FIG. 35

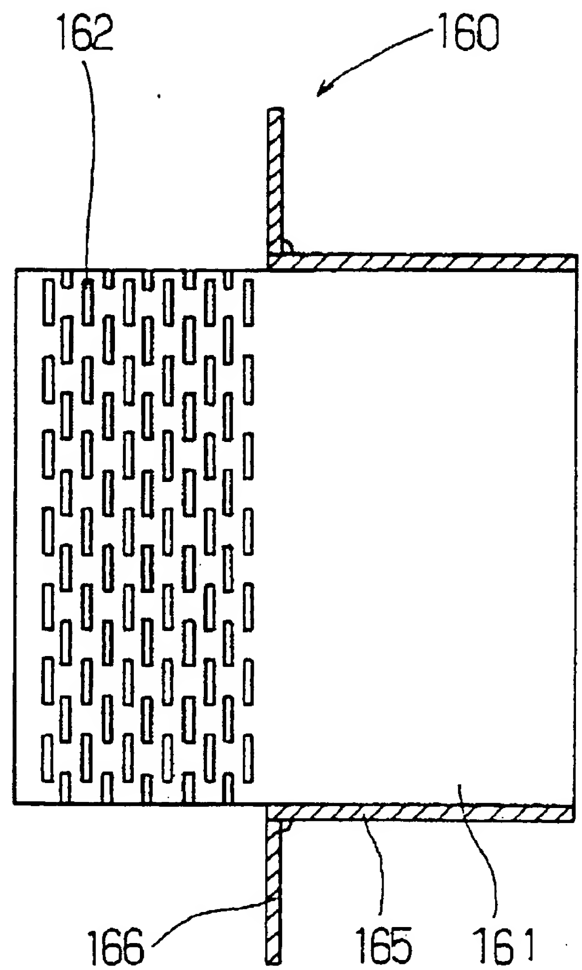


FIG. 36

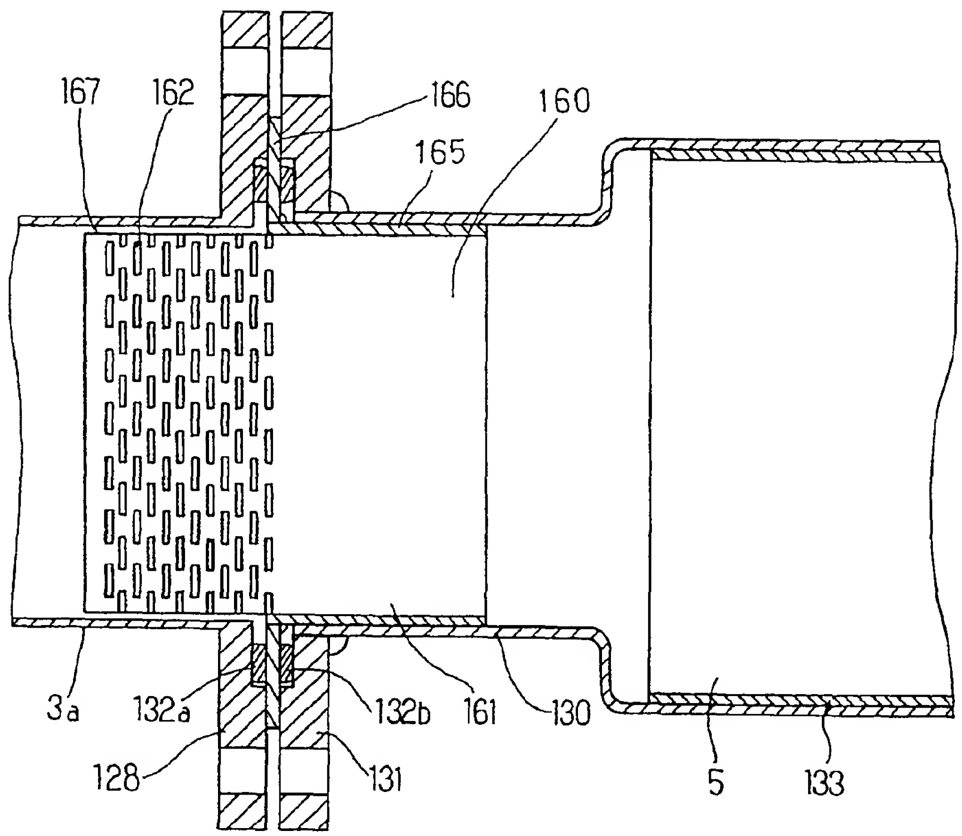


FIG. 37

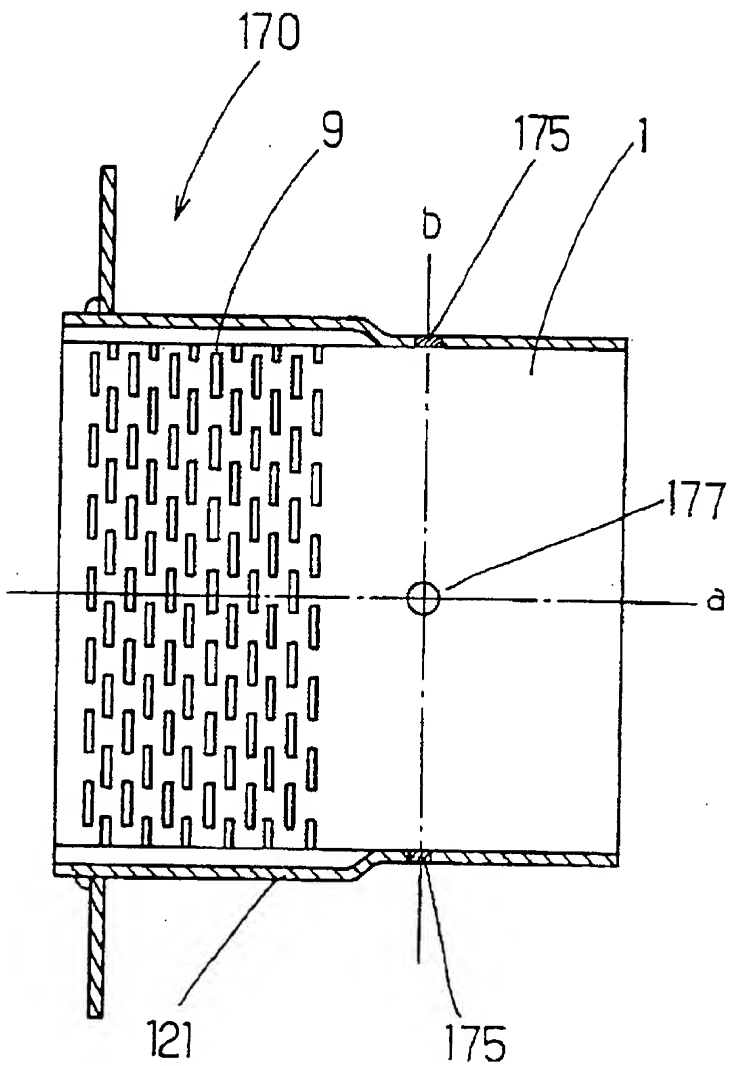


FIG. 38

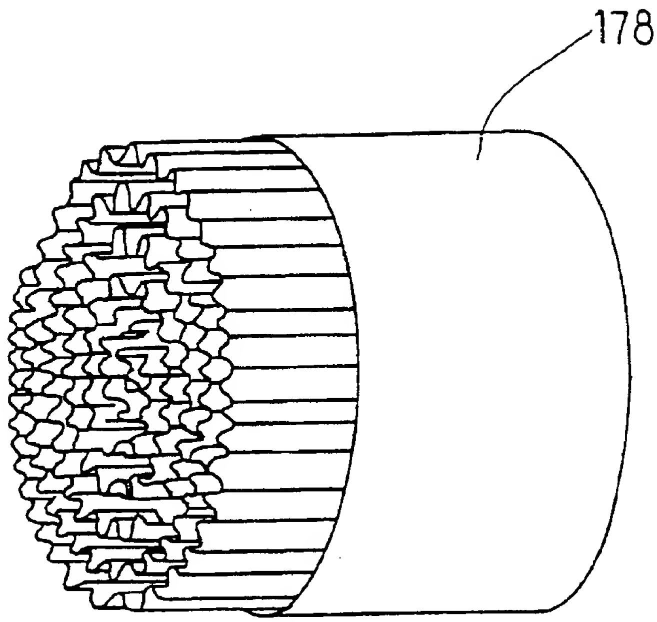


FIG. 39

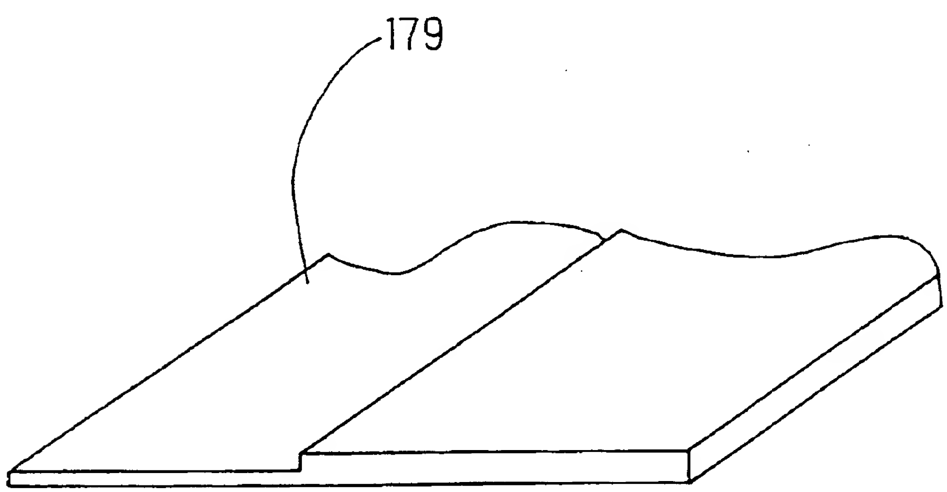


FIG. 40

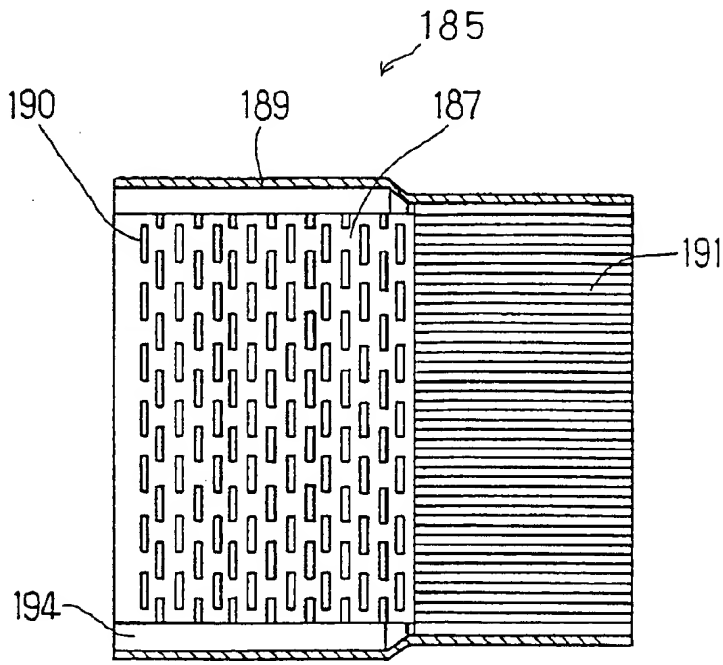


FIG. 41

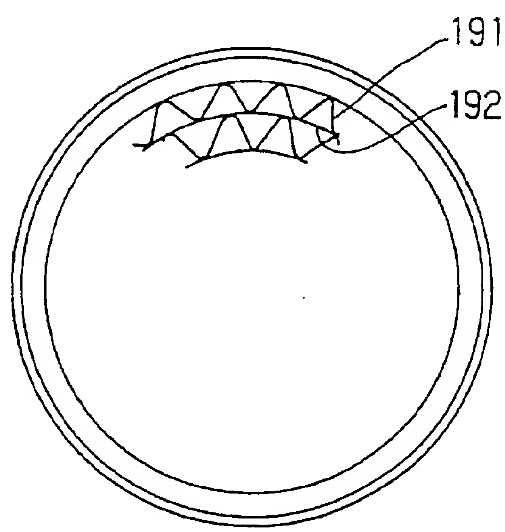


FIG. 42

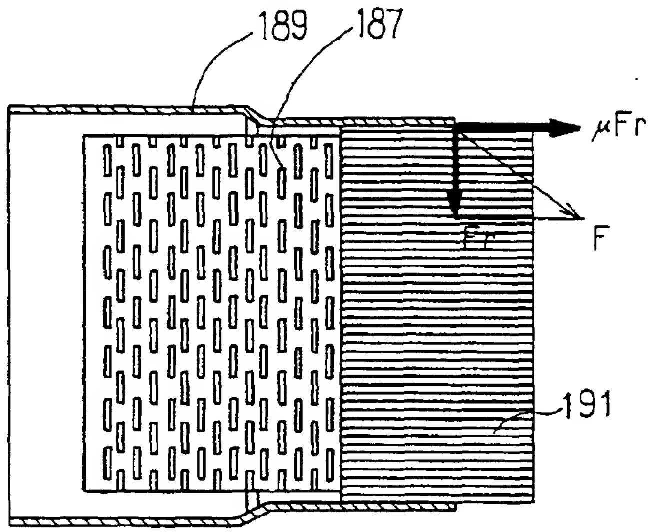


FIG. 43

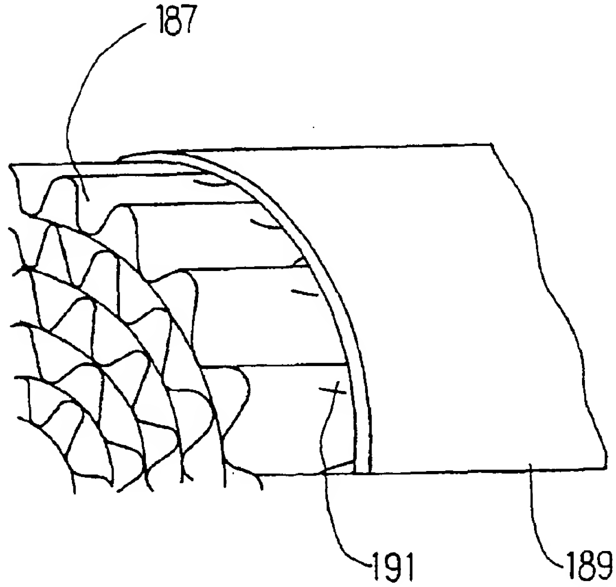


FIG. 44

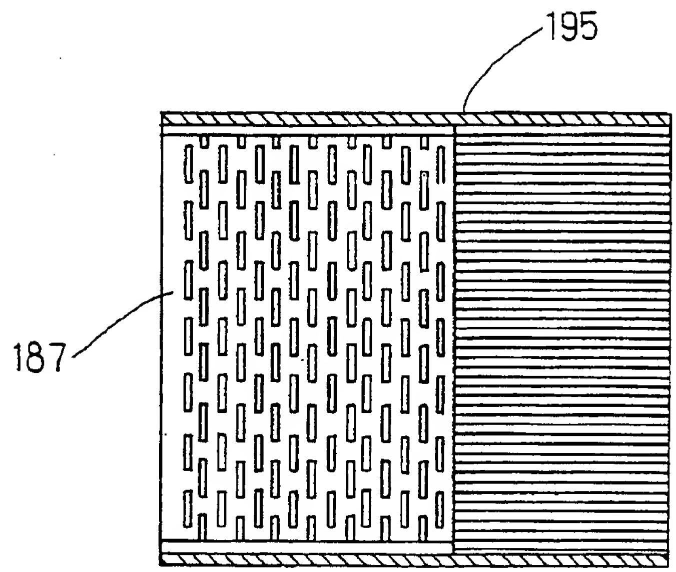


FIG. 45

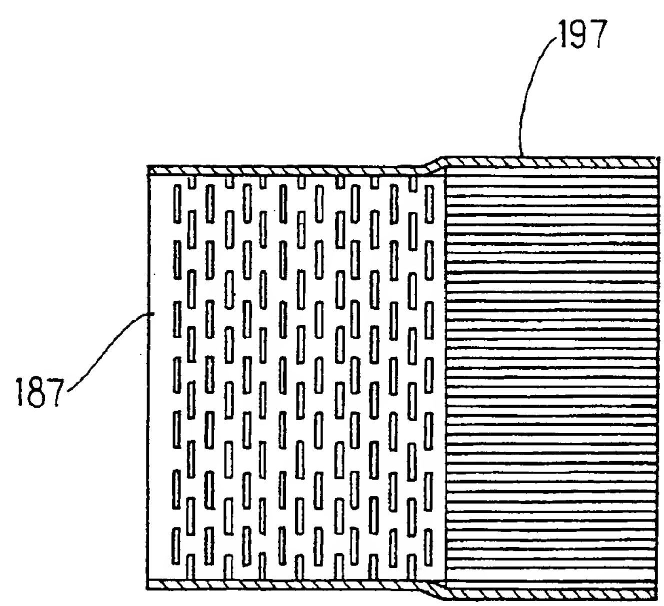


FIG. 46

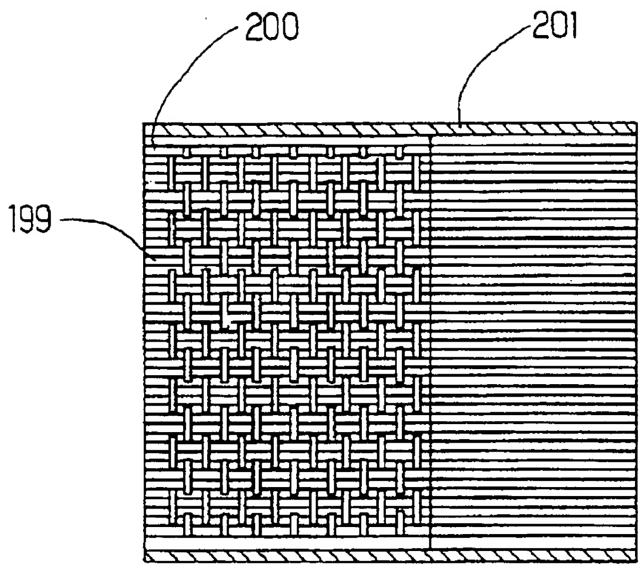


FIG. 47

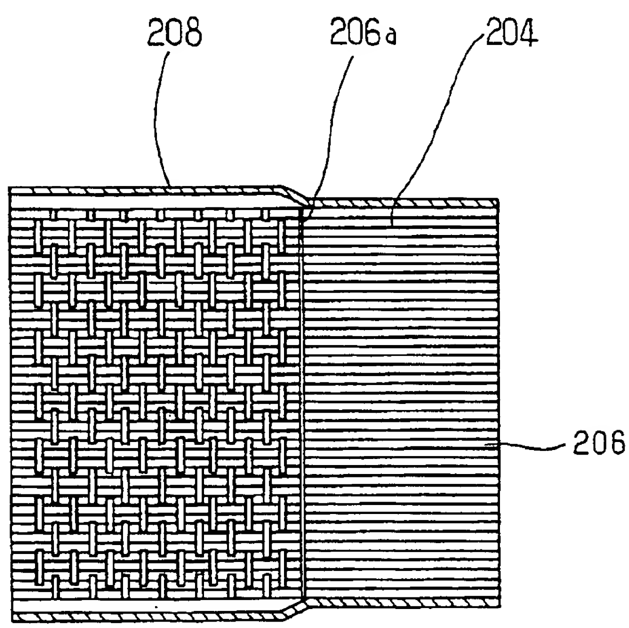


FIG. 48

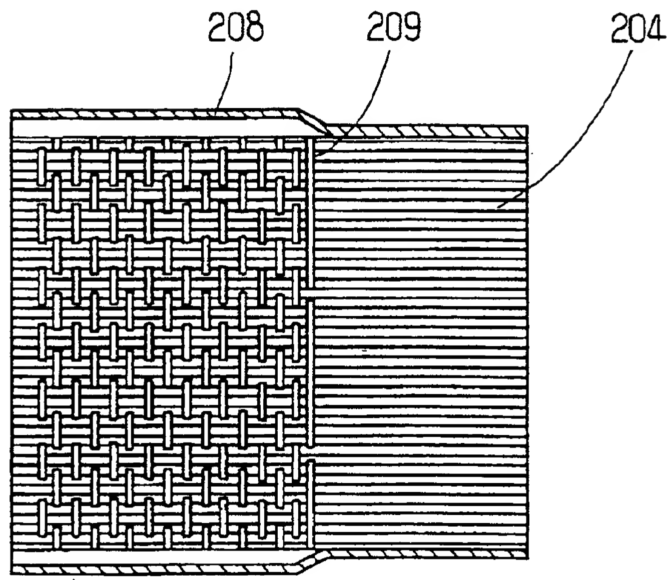


FIG. 49

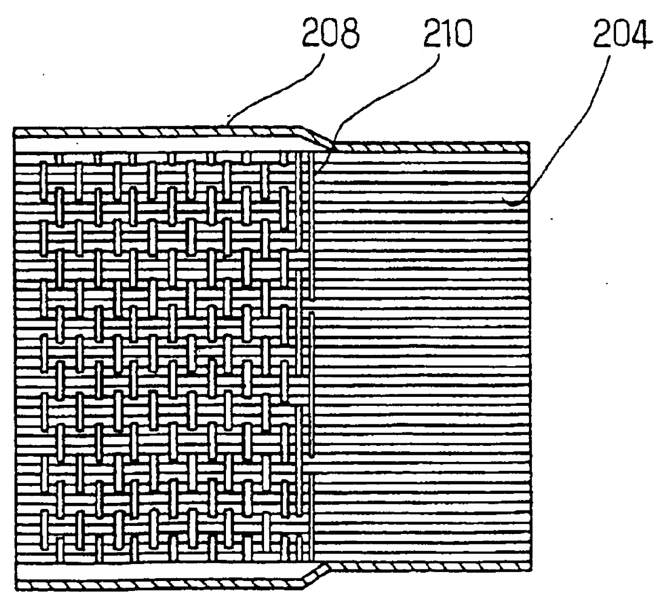


FIG. 50

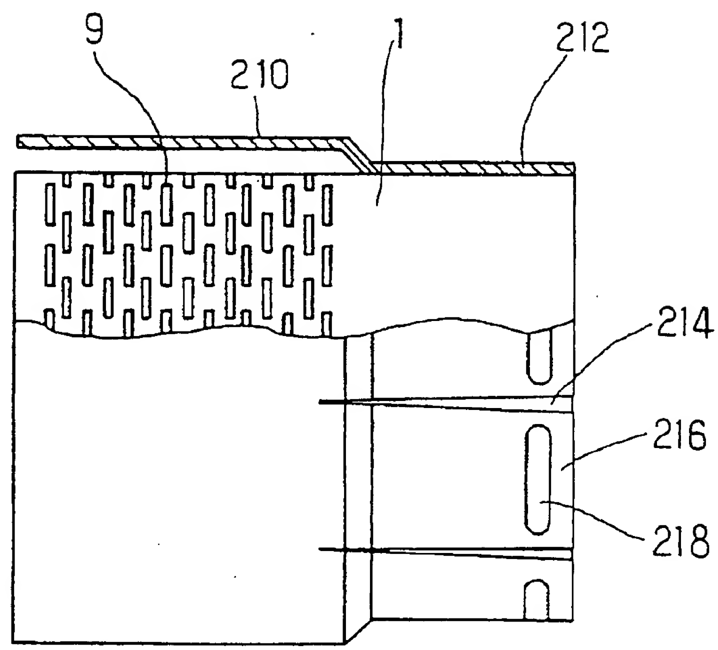


FIG. 51

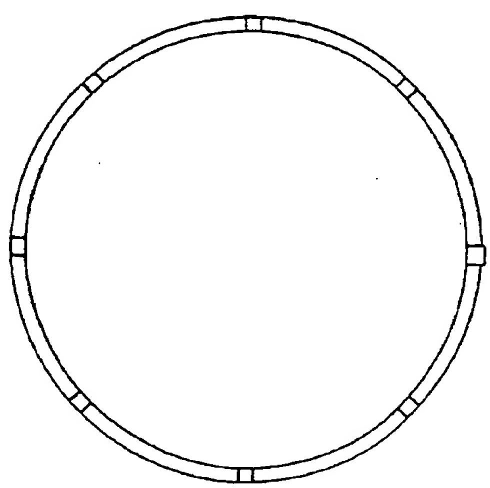


FIG. 52A

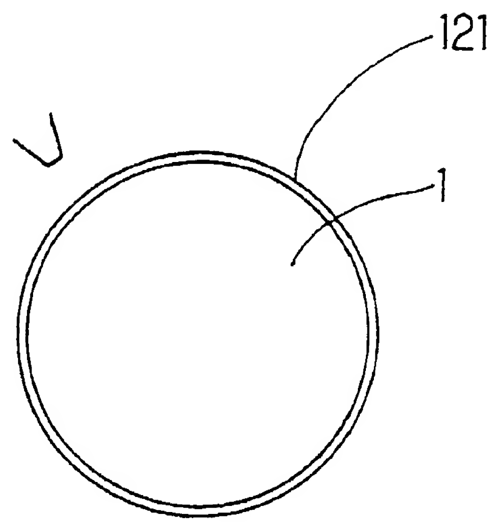


FIG. 52B

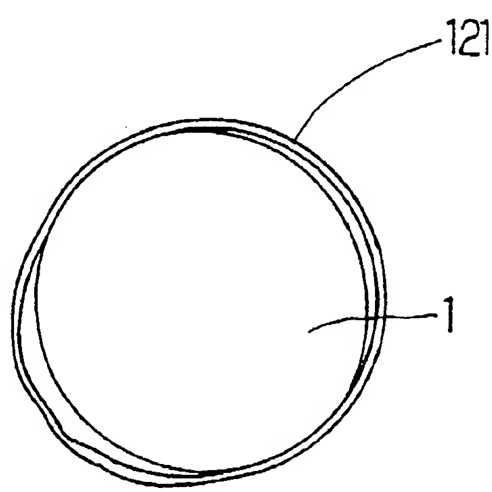


FIG. 53

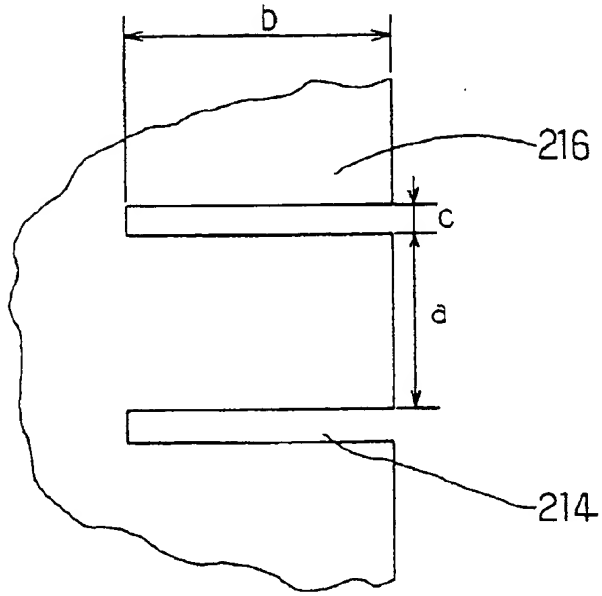


FIG. 54

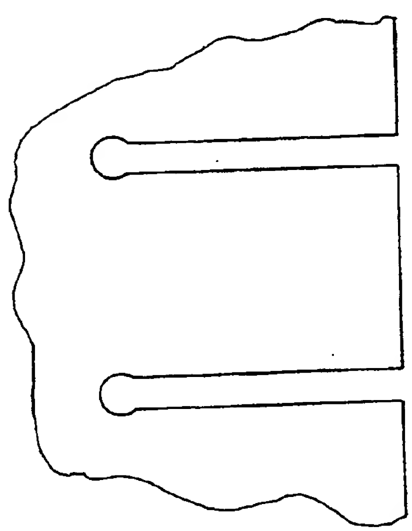


FIG. 55

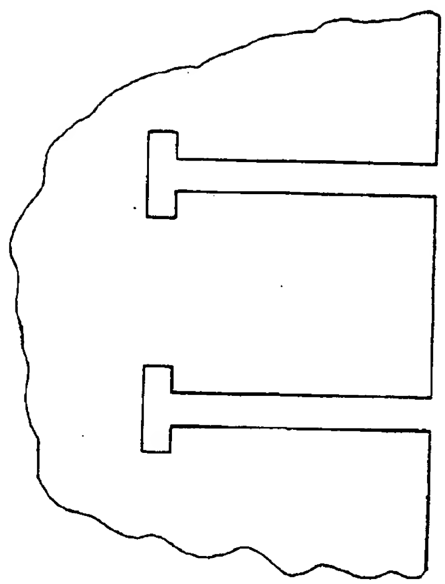


FIG. 56

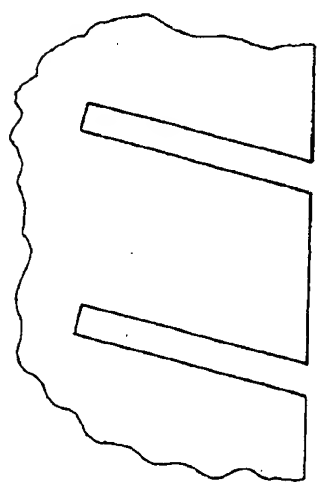


FIG. 57

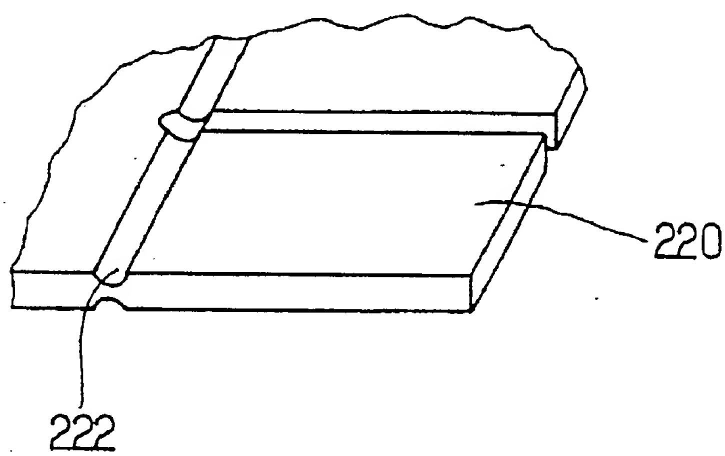


FIG. 58

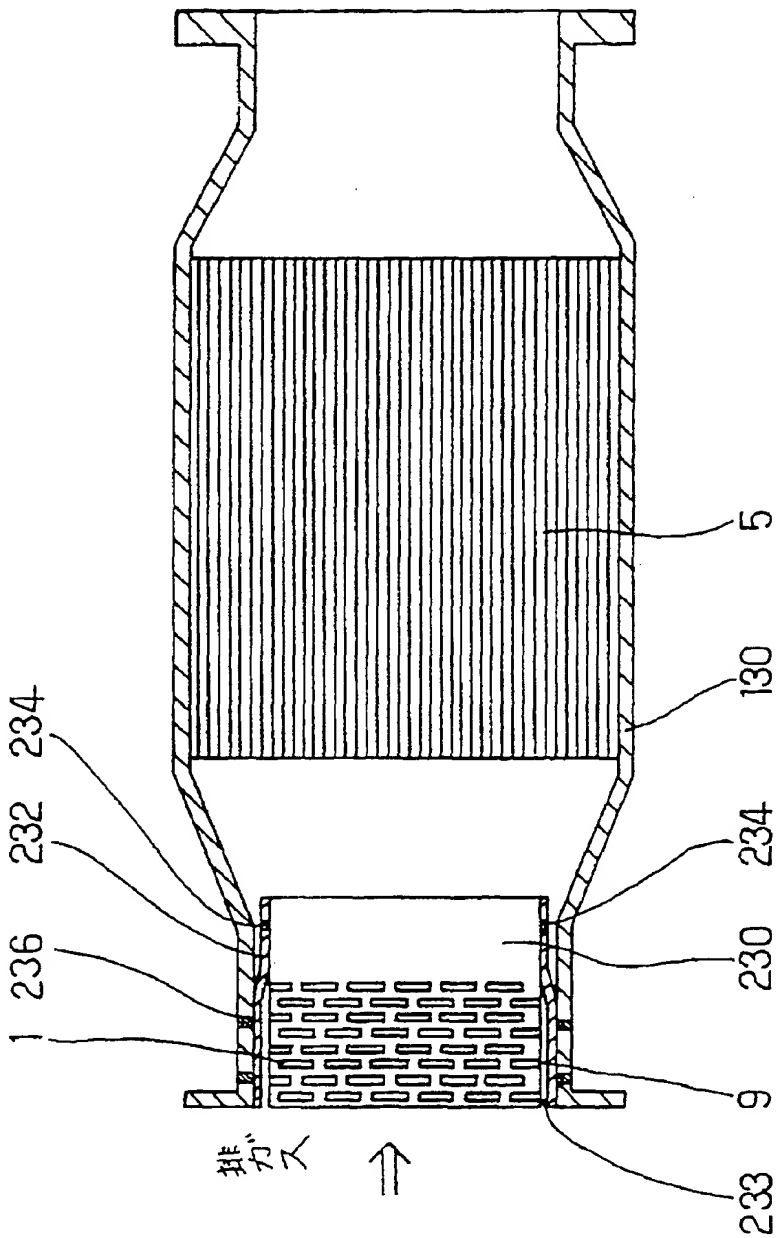


FIG. 59

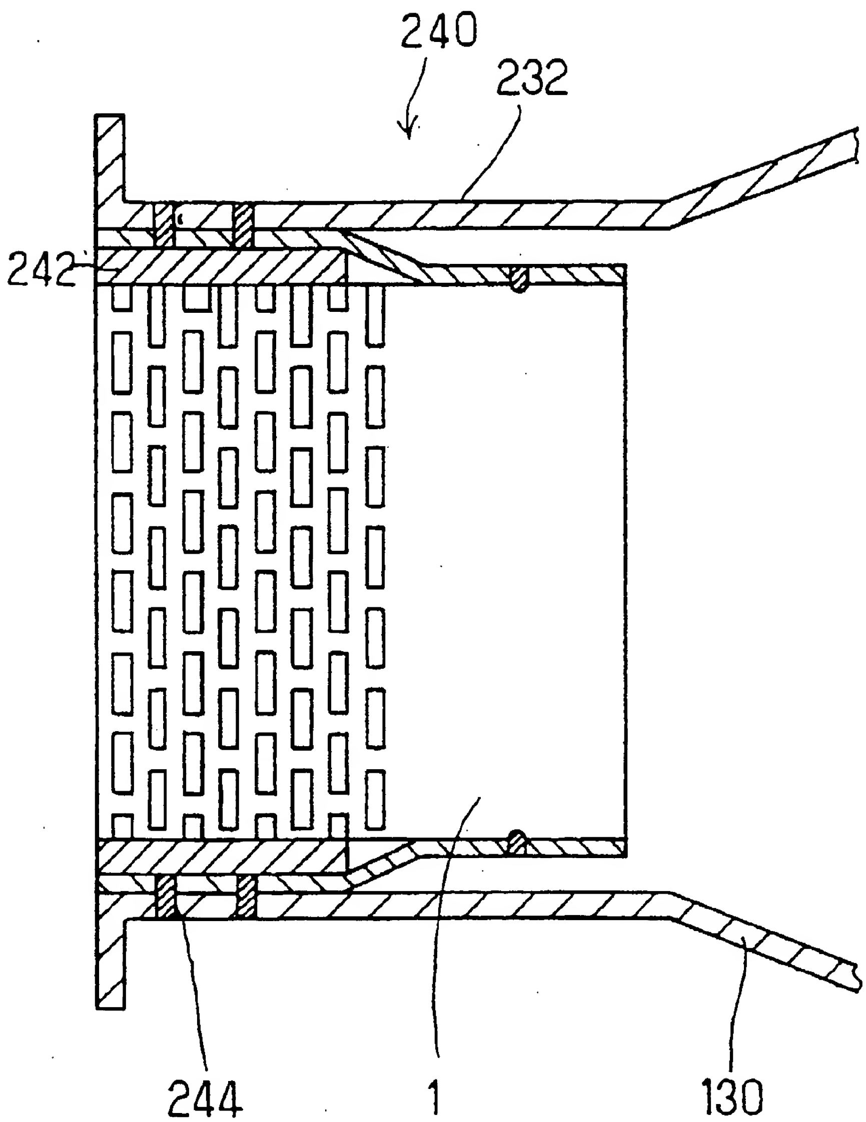


FIG. 60

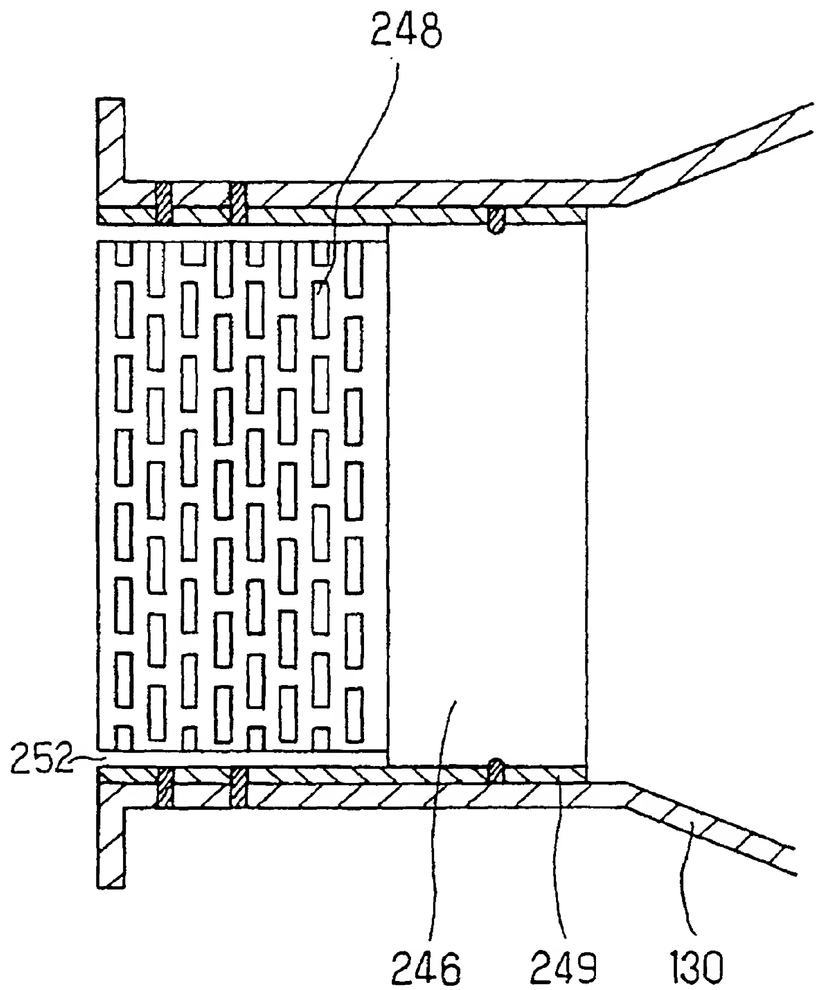


FIG. 61

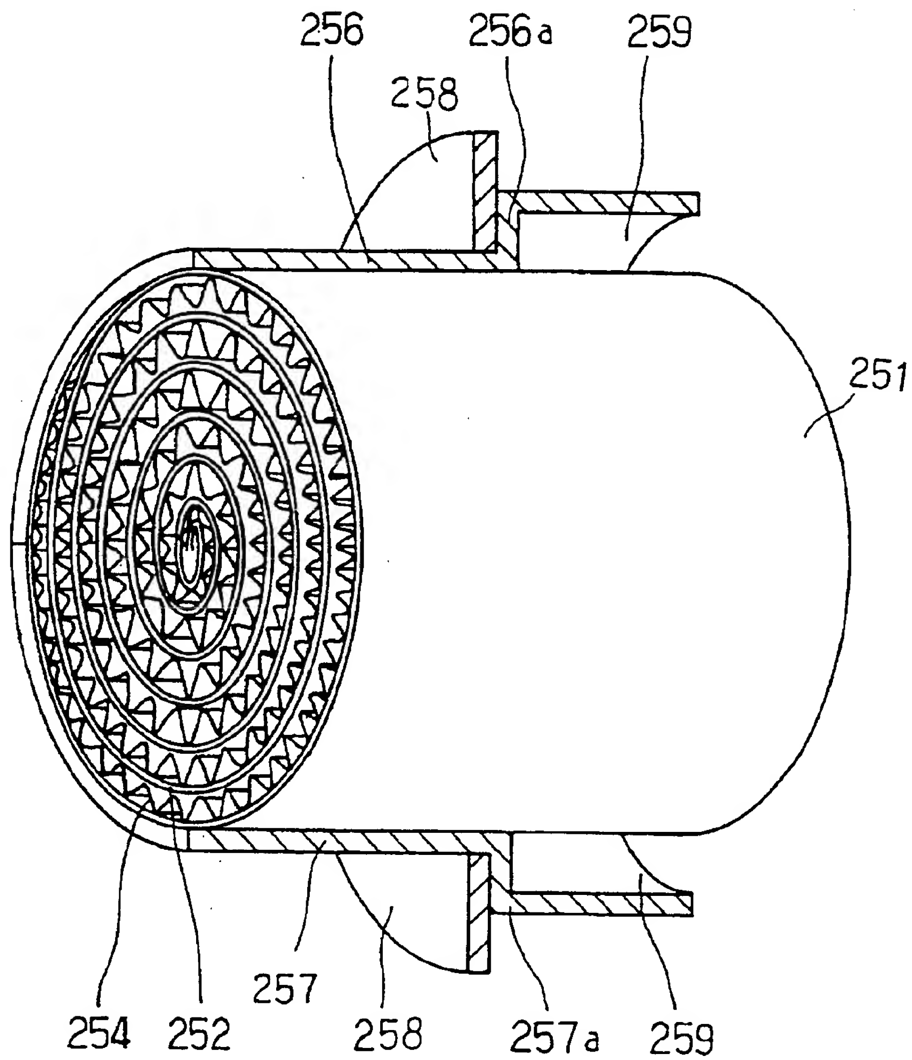


FIG. 62

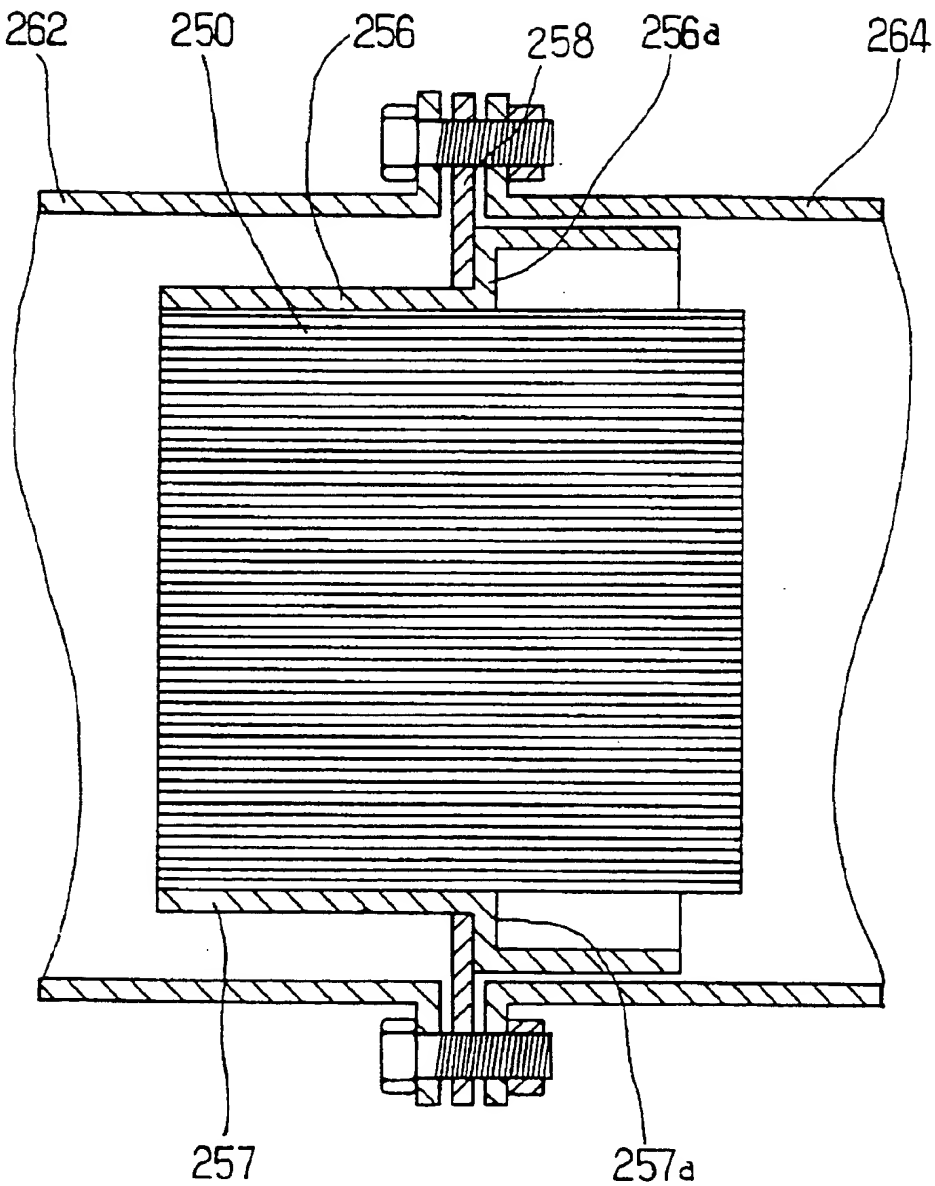


FIG. 63

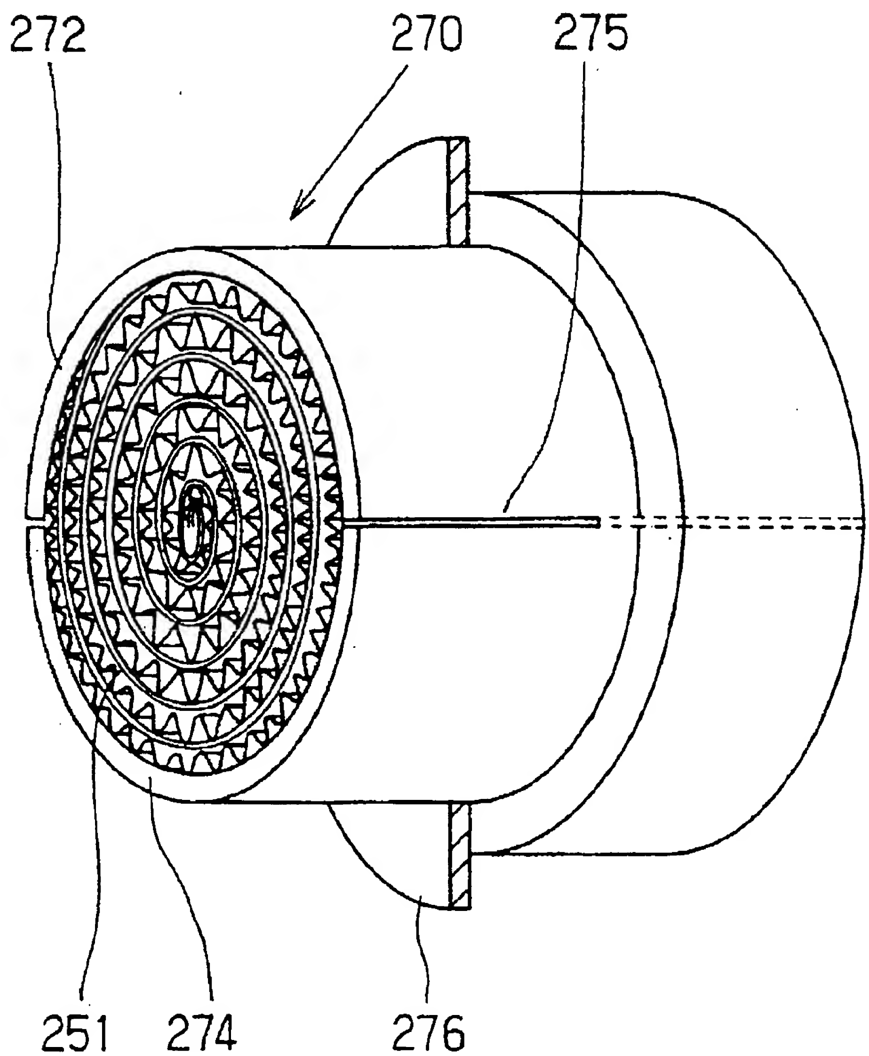
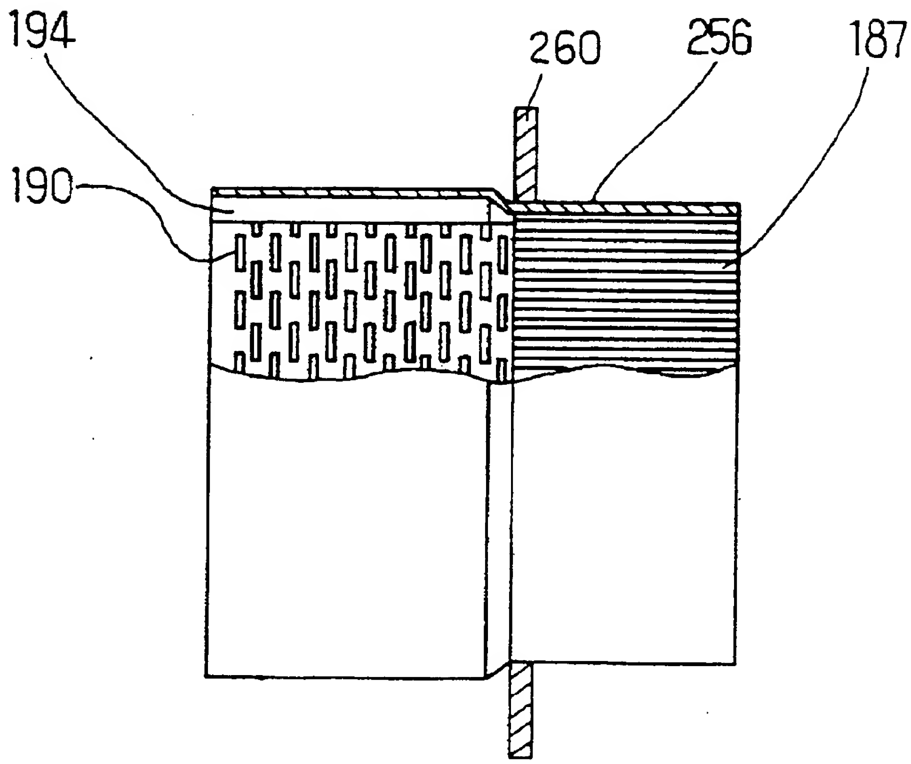


FIG. 64



METAL CARRIER

This application claims the benefit of the prior application Nos.5-56908 and 5-350447 filed respectively in Japan on Mar. 17, 1993 and Dec. 24, 1993 the content of which are incorporated hereinto by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention generally relates to a metal carrier. More particularly, the present invention relates to a metal carrier which is arranged in some place within an exhaust gas passage of an internal combustion engine for holding back a catalyst which is capable of reducing the exhaust gas from an internal combustion engine.

2. Description of the Related Art

Conventionally, metal carriers made of metal foils of band-like flat sheet and corrugated sheet wound or laminated together, such as the one disclosed in the Japanese Utility Model Publication Laid-Open No. 4-62316. On the other hand, a metal carrier provided with slit parts throughout metal foils, constructing the metal carrier holding the catalyst has been disclosed in the Japanese Examined Patent Publication No. 3-71177.

However, the metal carrier disclosed in the Japanese Utility Model Publication Laid-Open No. 4-62316 has a problem that this catalyst has so large a heat capacity that, at a low temperature, it takes a long time to achieve the temperature at which the catalyst is active, and as a result, until the catalyst is activated, unreduced exhaust gas from the internal combustion engine is exhausted into the atmosphere.

On the other hand, the metal carrier disclosed in the Japanese Examined Patent Publication No. 3-71177 has a problem that the strength of metal carrier itself is weakened by the slit parts formed throughout the metal foil.

SUMMARY OF THE INVENTION

An object of the present invention is to provide an improved metal carrier which can rapidly achieve the temperature at which the catalyst held by the metal carrier is active and, at the same time, has a high strength without enlarging the size thereof.

It is the first preferable mode of the present invention to provide a metal carrier for a catalyst converter which is composed of a flat sheet and a corrugated sheet alternatingly laminated, arranged in the course of an exhaust gas passage of an internal combustion engine, and a plurality of slit parts is formed on the metal carrier at only the upstream side of the exhaust gas passage.

It is the second preferable mode of the present invention to provide a metal carrier for a catalyst converter which is arranged in the course of an exhaust gas passage of an internal combustion engine, and includes a small heat capacity area formed only at the upstream side of the exhaust gas passage which is smaller in heat capacity than the downstream side of the exhaust gas passage.

By employing the above arrangement to embody the first preferable mode of the present invention, a plurality of slit parts are formed only at the upstream side of the exhaust gas passage of the metal carrier. Therefore, the heat capacity is so small only at this upstream side that the temperature of the metal carrier can easily be raised by the exhaust gas from the internal combustion engine.

After easily raising the temperature of the upstream side, the heat can easily be conducted to the downstream side of the metal carrier.

Furthermore, due to the composition with slit parts formed only at the upstream side, the high strength of the metal carrier can be obtained.

The second preferable mode of the present invention forms a small heat capacity area only at the upstream side of the exhaust gas passage of the metal carrier. Therefore, at the upstream side, the temperature of the metal carrier can easily be raised by the exhaust gas from the internal combustion engine.

After the temperature of the upstream side has easily been raised, the heat can easily be conducted to the downstream from the metal carrier by the flow of the exhaust gas.

Furthermore, due to the composition with slit parts formed only at the upstream side, the high strength of the metal carrier can be obtained.

By employing the present invention, a metal carrier which can hold a catalyst, can rapidly raise the temperature of the catalyst to activate the catalyst, and has a sufficient strength.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view illustrating the metal carrier of the first embodiment according to the present invention;

FIG. 2 is a composition view illustrating the entirety mounted with the metal carrier of the first embodiment according to the present invention;

FIG. 3 is a fragmentary sectional view illustrating the holding structure of the metal carrier;

FIG. 4 is a development view illustrating the flat sheet to be used for the metal carrier of the first embodiment;

FIG. 5 is a front view illustrating a manufacturing system for manufacturing the metal carrier of the first embodiment according to the present invention;

FIG. 6 is a top view illustrating a manufacturing system for manufacturing the metal carrier of the first embodiment according to the present invention;

FIG. 7 is a side view illustrating a manufacturing system for manufacturing the metal carrier of the first embodiment according to the present invention;

FIG. 8 is an illustrative view illustrating the position of the metal carrier and the engine applied for a comparative experiment;

FIG. 9A is a side view illustrating the metal carrier according to the present invention to be subjected to the comparative experiment;

FIG. 9B is a side view illustrating a metal carrier to be compared with in the comparative experiment;

FIG. 10 is a characteristic diagram illustrating the results of the comparative experiment;

FIG. 11 is a development view illustrating another embodiment of the slit shape to be used for the present invention;

FIG. 12 is a development view illustrating another embodiment of the slit shape to be used for the present invention;

FIG. 13 is fragmentary enlarged view illustrating the slit parts for describing the second embodiment;

FIG. 14 is a characteristic diagram illustrating the relation between the temperature and tensile strength of the material;

FIG. 15 is a perspective view illustrating the metal carrier of the second embodiment;

FIG. 16 is a characteristic diagram illustrating the relation between the temperature and tensile strength of the second embodiment and reference embodiment;

FIG. 17 is a fragmentary exploded view illustrating the metal carrier of the third embodiment;

FIG. 18 is a perspective view illustrating the metal carrier of the fourth embodiment;

FIG. 19 is a development view illustrating the flat sheet to be used for the metal carrier of the fourth embodiment;

FIG. 20 is a development view illustrating another embodiment of the slit shape to be used for the fourth embodiment;

FIG. 21 is a development view illustrating another embodiment of the slit shape to be used for the fourth embodiment;

FIG. 22 is a fragmentary exploded view illustrating the metal carrier of the fifth embodiment;

FIG. 23 is an illustrative view for illustrating the fifth embodiment;

FIG. 24 is an illustrative view for illustrating the fifth embodiment;

FIG. 25 is a perspective view illustrating the metal carrier of the fifth embodiment;

FIG. 26 is a development view illustrating another embodiment of slit shape to be used for the fifth embodiment;

FIG. 27 is a perspective view illustrating the metal carrier of the sixth embodiment;

FIG. 28 is a front view illustrating the metal carrier of the sixth embodiment;

FIG. 29 is a composition view illustrating the entirety mounted with the metal carrier of the sixth embodiment;

FIG. 30 is a fragmentary sectional composition view illustrating the mounted metal carrier of the sixth embodiment;

FIG. 31 is an illustrative view illustrating the measurement spots of the sixth embodiment;

FIG. 32 is a relational view illustrating the relation between the time and the temperature in the metal carrier of the sixth embodiment;

FIG. 33 is a cross-sectional view illustrating the metal carrier of the seventh embodiment;

FIG. 34 is a fragmentary composition view illustrating a part mounted with metal carrier of the seventh embodiment;

FIG. 35 is a cross-sectional view illustrating the metal carrier of the eighth embodiment;

FIG. 36 is a fragmentary composition view illustrating a part mounted with the metal carrier of the eighth embodiment;

FIG. 37 a cross-sectional view illustrating the metal carrier of the ninth embodiment;

FIG. 38 is a perspective view illustrating the metal carrier of another embodiment according to the ninth embodiment;

FIG. 39 is a schematic view illustrating the flat sheet forming the metal carrier of another embodiment according to the ninth embodiment;

FIG. 40 a cross-sectional view illustrating the metal carrier of the tenth embodiment;

FIG. 41 is a front view illustrating the metal carrier of the tenth embodiment;

FIG. 42 is an illustrative view illustrating the effects of the tenth embodiment;

FIG. 43 is an illustrative view illustrating the effects of the tenth embodiment;

FIG. 44 is a cross-sectional view illustrating the metal carrier of another embodiment according to the tenth embodiment;

FIG. 45 is a cross-sectional view illustrating the metal carrier of another embodiment according to the tenth embodiment;

FIG. 46 is a cross-sectional view illustrating the metal carrier of another embodiment according to the tenth embodiment;

FIG. 47 is a cross-sectional view illustrating the metal carrier of another embodiment according to the tenth embodiment;

FIG. 48 is a cross-sectional view illustrating the metal carrier of another embodiment according to the tenth embodiment;

FIG. 49 is a cross-sectional view illustrating the metal carrier of another embodiment according to the tenth embodiment;

FIG. 50 is a fragmentary sectional view illustrating the metal carrier of the eleventh embodiment;

FIG. 51 is a schematic rear view illustrating the metal carrier of the eleventh embodiment;

FIGS. 52A and 52B are illustrative views illustrating the problems with the eleventh embodiment;

FIG. 53 is an illustrative view illustrating the eleventh embodiment;

FIG. 54 is a fragmentary enlarged view illustrating another cutout shape of the eleventh embodiment;

FIG. 55 is a fragmentary enlarged view illustrating another cutout shape of the eleventh embodiment;

FIG. 56 is a fragmentary enlarged view illustrating another cutout shape of the eleventh embodiment;

FIG. 57 is a fragmentary enlarged view illustrating another cutout shape of the eleventh embodiment;

FIG. 58 is a cross-sectional view illustrating the catalyst converter of the twelfth embodiment;

FIG. 59 is a cross-sectional view illustrating the catalyst converter of the thirteenth embodiment;

FIG. 60 is a cross-sectional view illustrating the catalyst converter of the fourteenth embodiment;

FIG. 61 is a fragmentary sectional view illustrating the metal carrier of the fifteenth embodiment;

FIG. 62 is a cross-sectional view illustrating the mounting of the metal carrier of the fifteenth embodiment; and

FIG. 63 is a fragmentary sectional view illustrating the metal carrier of the sixteenth embodiment.

DETAILED DESCRIPTION OF THE EMBODIMENTS

First Embodiment

Referring to FIGS. 1 through 3, the first embodiment according to the present invention will now be described.

FIG. 2 is a fragmentary sectional view illustrating exhaust manifolds *3a* and *3b*, which constitute the exhaust gas passages of an engine (internal combustion engine) 2, including metal carriers for catalyst converter, 1, which are the metal carriers of the first embodiment according to the present invention.

The engine 2 is, e.g., of V8 and 4000 cc specifications. Eight pieces of exhaust manifolds extended from the engine 2 are grouped into 2 pieces of exhaust manifold *3a* and *3b* which consist of 4 pieces of exhaust manifolds respectively.

Within each exhaust manifolds *3a* or *3b*, the metal carrier 1 of the first embodiment is arranged in some place and a start catalyst 5 having a large capacity of 1300 cc is arranged in the immediate downstream therefrom.

FIG. 1 is a perspective view illustrating the metal carrier 1 of the first embodiment, and FIG. 3 is a view illustrating the holding structure of the metal carrier 1 and catalyst converter 5 at the downstream side from the engine 2.

The metal carrier 1 of the first embodiment is composed of a flat sheet 7 and a corrugated sheet 8.

Both the flat sheet 7 and the corrugated sheet 8 are band-like metal sheets of 80 mm in width and 0.03 to 0.20 mm in thickness, composed of chrome (Cr, 18 to 24 wt %), aluminum (Al, 4.5 to 5.5 wt %), rare earth metal elements (REM, 0.1 to 0.2 wt %) and the rest, iron (Fe), respectively (Fe-Cr-Al composition).

Slit parts 9 are formed at one side of the flat sheet 7 and corrugated sheet 8, whereas each slit part is shaped roughly rhombic of 15 mm wide. The slit parts 9 are continuously arranged at a regular interval of 0.16 mm. Furthermore, as illustrated in FIG. 4, the roughly rhombus forming the slit parts 9 are adjacently arranged to be parallel with each other.

The corrugated sheet 8 has a pitch of 2.5 mm and a height of 1.25 mm.

The flat sheet 7 and the corrugated sheet 8 are alternatingly wound to form the metal carrier 1 of the first embodiment with the slit parts formed only at one end part as illustrated in FIG. 1.

As illustrated in FIG. 3, the metal carrier 1 is fixedly held by a supporting rod 18 within an outer ring 10 via a short-fiber inorganic heat-insulation material of 5 mm thick, 14, and a long-fiber inorganic heat-insulating material of 1 mm thick, 16, whereas the outer ring 10 includes an exhaust manifold mounting flange 10*a* and a start catalyst mounting flange 10*b*. The supporting rod 18 is arranged in six places coincidently with the portion of the metal carrier 1 with no slit parts 9, whereas those six places are almost equally arranged in the circumferential direction with three places at the upstream side and the three places at the downstream side. By welding one end of the supporting rod 18 to the outer surface of the metal carrier 1 and the other end thereof to the outer ring 10, the metal carrier 1 is fixedly held by the outer ring 10.

The start catalyst 5, a monolithic catalyst carrier, is fixedly held within an outer ring for start catalyst, 20, via a spacer part (not illustrated), whereas the outer ring 20 includes a metal carrier mounting flange 20*a* and a exhaust pipe mounting flange 20*b*.

The outer ring 10 and the outer ring for start catalyst, 20, are integrated by connecting the start catalyst mounting flange 10*b* on the outer ring 10 and the metal carrier mounting flange 20*a* on the outer ring 20 to each other with bolts 22. Furthermore, by connecting the exhaust manifold mounting flange 10*a* to flanges 24*a* and 24*b* arranged in the downstream of the exhaust manifold 3 illustrated in FIG. 2 with bolts (not illustrated), the metal carrier 1 and the start catalyst 5 are arranged in the downstream of the exhaust manifolds 3*a* and 3*b* extended from the engine 2.

Particularly at this time, the slit parts 9 formed in the flat sheet 7 and corrugated sheet 8 of the metal carrier 1 are arranged to be at the side of the engine 2.

Next, the procedure for manufacturing the metal carrier 1 will be described.

In the first place, a flat sheet with the roughly rhombic slit parts 9 illustrated in FIG. 4 is obtained by a method of shearing (lath metal), pressing or etching.

The dimensions of the rhombus of the slit parts 9 illustrated in FIG. 4 are set to the following:

a (vertical length of rhombus)=2 mm

b (horizontal length of rhombus)=1 mm

c (slit-to-slit length)=0.16 mm

d (slit width)=15mm

e (metal sheet width)=80 mm

By forming a corrugation at a pitch of 2.5 mm and a height of 1.25 mm on the flat sheet with slit parts formed by the above method, the corrugated sheet 8 with the slit parts 9 of 15 mm wide at one end can be obtained. In this example, the slit width is about 18% of the sheet width.

The flat sheet 7 and corrugated sheet 8 with the slit parts 9 formed therein are alternatingly wound and laser welded on a manufacturing system illustrated in FIGS. 5 through 7.

Here, FIG. 5 is a front view illustrating the manufacturing machine, FIG. 6 is a top view thereof, and FIG. 7 is a side view thereof.

Winding and laser welding methods will specifically be described.

The flat sheet 7 is wound around a guide sheet 32, and the corrugated sheet 8 is wound around a guide sheet 34 (FIG. 6). The flat sheet 7 is guided by a tension roller for flat sheet controlling, 36, and the corrugated sheet 8 is guided by tension rollers for corrugated sheet controlling, 38 and 40, to a guide sheet 42. By driving the guide sheet 42 by a motor 43, the flat sheet 7 and the corrugated sheet 8 are wound while being laminated together.

Furthermore, during this winding and laminating, the flat sheet 7 and the corrugated sheet 8 are laser welded by YAG lasers 44 and 46 via laser guns 48 and 50.

As the laser welding is applied to the points on which the flat sheet 7 contacts the crests of the corrugated sheet 8, the extremely precise positioning of these points is required. To meet this requirement, a manufacturing system 30 employs laser displacement sensors 52, 54 and 56 for detecting the laser welding position. For detecting the displacement, non-contact overcurrent type sensors or contact type sensors may be used instead of these laser type sensors. Furthermore, according to the detection signals outputted from these sensors, a servo motor (not illustrated) is driven, and accordingly X–Y tables 62 and 64 for fixing the laser guns 48 and 50 are shifted.

Specifically, the laser displacement sensor 52 detects a gap between the laser gun 48 and the metal carrier 1, and outputs the detection signals to the servo motor (not illustrated). The laser displacement sensor 54, on the other hand, detects a gap between the laser gun 50 and the corrugation valley formed on the corrugated sheet 8, and outputs the detection signals to the servo motor (not illustrated). The laser displacement sensor 56 detects the position of the corrugation formed on the corrugated sheet 8 at the crest side in a half-pitch delayed position, and outputs the detection signals to the servo motor (not illustrated). The servo motor drives the X–Y tables 62 and 64 to their proper positions according to these detection signals.

Controlled as described in the above, the manufacturing system 30 can precisely laser weld the flat sheet 7 and the crests of the corrugated sheet 8.

In this way, the flat sheet 7 and the corrugated sheet 8 can be wound and laminated together, the slit parts 9 can be formed only at one end side, and the metal carrier 1 laser welded at the specified position of the flat sheet 7 and crests of corrugated sheet 8 can be obtained.

For employing this metal carrier for a catalyst converter, the metal carrier is heated at 800° to 1200° C. for 1 to 10 hours to deposit the oxide of Aluminum over the metal surface. Then, the metal carrier is impregnated in a slurry containing γ-Al_2O_3 for wash coat process. Following the wash coat process, the metal carrier is impregnated in an

aqueous solution of catalytic metal, such as platinum (Pt) or rhodium (Rh), and then fired again.

After completing the above processes, the metal carrier for catalyst converter in which the catalyst is held can be obtained.

The first embodiment functions as follows:

In the first embodiment, the functions described below can be achieved by arranging the slit parts **9** of 15 mm wide formed at one end part of the metal carrier **1** at the upstream side of the exhaust manifolds **3a** and **3b** constituting the exhaust gas passages.

After the engine **2** starts, the exhaust gas emitted from each cylinder exhausting process flows through the exhaust manifolds **3a** and **3b**, and collides with the slit parts **9** positioned at the upstream side of the metal carrier **1**. As a result, the temperature of the slit parts **9** rises most rapidly also due to the small heat capacity resulted from the deliberate formation of the slits. When the temperature reaches the activation temperature of the catalyst held by the metal carrier **1** (approx. 300° C. in the case of the present invention), the exhaust gas is begun to be purified at the upstream side of the metal carrier **1**. During this purification, the oxidations of the hydrocarbon (HC) and carbon monoxide (CO) contained in the exhaust gas generate reaction heat. This reaction heat is conducted towards the downstream, and, together with the heat conduction within the metal carrier **1**, successively causes the temperature rise and catalyst activation from the slit parts **9** towards the downstream.

Consequently, in tens of seconds after the engine **2** starts, the catalyst itself can be activated throughout the metal carrier **1**.

In the same way, in the start catalyst **5** arranged in the immediate downstream from the metal carrier **1**, the catalyst activation is successively caused from around the upstream side towards the downstream, and in about 30 seconds after the engine **2** starts, the catalyst activation can be achieved throughout the start catalyst **5**.

In the first embodiment, even if a large volume of exhaust gas flows when the engine **2** is heavily loaded, more than 80% of the HC and CO within the exhaust gas can be purified by the metal carrier **1** and the start catalyst **5**.

The temperature rise characteristics were compared between the metal carrier according to the present invention and a conventional metal carrier.

In comparative experiment, the metal carrier according to the present invention and the conventional metal carrier were composed as illustrated in FIG. **8**. In the metal carrier **100** according to the present invention, slit parts were formed only at one end part of a flat sheet and corrugated sheet as formed in the first embodiment. In the conventional metal carrier, a band-like sheet material with no slit parts on the metal carrier **100** was employed. Both the metal carriers were exactly the same in size.

The metal carriers are illustrated in FIGS. **9A** and **9B** respectively, which were arranged at such a distance that the exhaust gas emitted from the engine could reach about 300° C. in 2 to 3 seconds after the engine started.

The temperature rise in each metal carrier was measured at 8 mm distant from the upstream side of the metal carrier towards the downstream side and in the axially central part of the metal carrier.

FIG. **10** illustrates the results of the above comparative experiment. In this figure, A denotes the temperature state of the exhaust gas at 20 mm upstream from each catalyst carrier, B denotes the temperature state within the metal carrier according to the present invention, and C denotes the temperature state within the conventional metal carrier.

As it is evident from FIG. **10**, it took the metal carrier according to the present invention to reach about 300° C. in 4 to 5 seconds after the engine started, while it took the conventional metal carrier 8 to 9 seconds after the engine started.

This tells that by forming the slit parts at the upstream side of the metal carrier, the heat capacity of the portion exposed to the exhaust gas at the highest temperature could be reduced, and rapid temperature rise could be achieved.

Although the slit parts are rhombic in the first embodiment, the present invention is not limited to this shape but may employ rectangular slit parts **66** in FIG. **11** or corrugated slit parts **68** in FIG. **12**.

Furthermore, though the flat sheet and the corrugated sheet are laser welded for connection in the above embodiment, the present invention is not limited to this connection way but may employ brazing or spot welding.

Moreover, though the flat sheet and the corrugated sheet are alternatingly wound to obtain the metal carrier in the first embodiment, the present invention is not limited to this way but may alternatingly laminate the flat sheet and the corrugated sheet to obtain the metal carrier.

Second Embodiment

The temperature rise characteristics can be obtained by sufficiently reducing the heat capacity by forming the slit parts **9** in both the flat sheet **7** and the corrugated sheet **8** as in the first embodiment. A problem with this method, however, is that the portions of the flat sheet **7** and corrugated sheet **8** in which the slit parts **9** are formed sustain reduced strength.

For example, if the slit parts **69** in FIG. **13** are formed as illustrated, H and D parts should be narrowed or W and h parts should be enlarged to reduce the apparent heat capacity.

As illustrated in FIG. **14**, however, the materials composing the flat sheet and the corrugated sheet have smaller allowable stress as the temperature rises, and for this reason, durability and strength should be taken into account. Therefore, from the viewpoint of durability and strength, the slit shape is tend to be restricted.

In order to solve this problem, the second embodiment is so arranged that only either the flat sheet or the corrugated sheet is provided with the slit parts in the front part thereof which is coincided with the inflow direction of the exhaust gas, and the other sheet is not provided with any slit parts, and most part of the required strength is borne by the non-slit parts.

FIG. **15** is a development view of the metal carrier **70** of the second embodiment.

The metal carrier **70** is formed by an alternate winding of a flat sheet **71** with no slit parts and a corrugated sheet **73** with slit parts **72** formed at an end part of one side.

In this arrangement, the metal carrier **70** which has both temperature rise performance and durability to a sufficient extent can be obtained.

FIG. **16** is a characteristic view illustrating the specific comparison in specific temperature rise performance.

In this figure, **75** denotes the temperature of the gas flows into the metal carrier, **76** denotes the case with the metal carrier of the first embodiment with slit parts formed both in the flat sheet and in the corrugated sheet, **77** denotes the case with the metal carrier of the second embodiment with slit parts formed only in the flat sheet, **78** denotes the metal carrier of the second embodiment with slit parts formed only in the corrugated sheet, and **79** denotes the case with the conventional metal carrier with no slit parts.

As it is evident from FIG. **16**, the metal carrier with slit formed in either the flat sheet or the corrugated sheet can

achieve sufficient temperature rise characteristics compared with the conventional metal carrier.

Furthermore, in the second embodiment, as the slit parts are formed only either in the flat sheet or in the corrugated sheet, the slit shape can be made smaller compared with the first embodiment, and the strength can be borne by the other flat sheet or corrugated sheet with no slit parts.

As a result, the second embodiment has secondary effects that the surface area for heat capacity per unit volume of the slit parts can be enlarged and the supporting volume per unit volume can also be increased.

Although the second embodiment is so arranged that slit parts are formed in the corrugated sheet but not formed in the flat sheet, the second embodiment is not limited to this arrangement but may be so arranged that slit parts are formed in the flat sheet but not formed in the corrugated sheet.

Furthermore, though in the first embodiment, the metal carrier is obtained by alternatingly winding the flat sheet and the corrugated sheet, the present invention is not limited to this method but may obtain the metal carrier by alternatingly laminating the flat sheet and the corrugated sheet.

Third Embodiment

FIG. **17** illustrates the metal carrier **80** of the third embodiment. This metal carrier **80** is formed by laminating and winding a corrugated sheet **83** provided with cutouts **82** at one end at the upstream side when a flat sheet **81** and the metal carrier **80** are arranged within the exhaust gas passage to reduced the heat capacity.

Also in this arrangement, the same effects as those of the second embodiment can be obtained.

Also in this embodiment, cutouts may be formed only in the flat sheet **81**.

What is more, though the metal carrier **80** is obtained by alternatingly winding the flat sheet and the corrugated sheet in the above embodiment, the metal carrier **80** may be obtained by simply laminating the flat sheet and the corrugated sheet together.

Moreover, in the first embodiment, though the metal carrier is obtained by alternatingly winding the flat sheet and the corrugated sheet, the present invention is not limited to this method but may obtain the metal carrier by alternatingly laminating the flat sheet and the corrugated sheet.

Fourth Embodiment

The fourth embodiment will now be described in depth.

FIG. **18** is a type view of a metal carrier **90** according to the present invention.

The metal carrier **90** is formed by laminating or winding a flat sheet **91** and a corrugated sheet **92**.

As is the case with the first embodiment, the flat sheet **91** and the corrugated sheet **92** are of Fe-Cr-Al composition with Cr (18 to 24 wt %), Al (4.5 to 5.5 wt %), REM (0.1 to 0.2 wt %) and the rest, Fe, respectively.

The flat sheet **91** and the corrugated sheet **92** are 60 mm wide and 0.03 to 0.20 mm thick. Slit parts **93** are formed for a width of 30.95 mm in both the flat sheet **91** and the corrugated sheet **92**. In this example, the slit width is about 52% of the sheet width.

Furthermore, the slit parts **93** are not formed throughout the circumferential lengths of the flat sheet **91** and corrugated sheet **92** but at least either the flat sheet **91** or the corrugated sheet **92** are provided with non-slit parts **94** in an exhaust gas flow direction as denoted by x in FIG. **18**.

FIG. **19** is a development view illustrating the details of the shape of the slit parts **93** formed in the flat sheet **91** employed in the fourth embodiment.

Each slit of slit parts **93** has a slit width **93***a* of 0.55 mm, a slit length **93***b* of 1.7 mm and a slit interval **93***c* of 0.6 mm, and each line of the slit parts **93** is displaced by a half pitch from the adjacent lines thereof with the mesh width **93***d* of 0.4 mm therebetween. The slit groups **95** with a width **93***e* of 47.7 mm, which is an assembly of the slits parts **93** are successively formed with the non-slit parts **94** of a width **94***f* of 2 mm therebetween.

The corrugated sheet **92** is also provided with the slit parts **93** and the non-slit parts **94** in the same arrangement as the slit groups **95** formed in the flat sheet **91**, and furthermore, uneven parts are successively formed at a pitch of 4.77 mm and a height of 1.75 mm.

Then, by alternatingly laminating and winding the flat sheet **91** and the corrugated sheet **92**, the metal carrier **90** of the fourth embodiment with non-slit parts in an exhaust gas flow direction denoted by x is formed.

Then, the functions of the fourth embodiment according to the present invention will be described.

In the fourth embodiment, the metal carrier **90** is formed with the non-slip parts **94** of 2 mm wide in the slit parts of 30.95 mm wide at every 47.7 mm.

This metal carriers **90** are arranged within the exhaust manifolds **3***a* and **3***b* constituting exhaust gas passages instead of the metal carriers **1**.

As illustrated in FIG. **2**, after the engine **2** starts, the exhaust gas emitted from each cylinder exhausting process flows through the exhaust manifolds **3***a* and **3***b*, and collides with the slit groups **95** positioned at the upstream side of the metal carrier **90**. As a result, the temperature of the slit group **95** rises most rapidly also due to the small heat capacity resulted from the deliberate formation of the slits.

Incidentally, the heat conductivity of the slit groups **95** of the fourth embodiment is approx. 1/10 of the case where no slit parts **93** are provided.

When the temperature of the slit groups **95** reaches the activation temperature of the catalyst held by the metal carrier **90** (about 300° C.), the exhaust gas is begun to be purified, and the catalyst activation is successively made towards the downstream by the reaction heat and the heat conduction within the metal carrier **90**.

In this way, in seconds after the engine **2** starts, the catalyst activation can be made throughout the metal carrier **90**.

On the other hand, the pulsation of the exhaust gas collided with the slit groups **95** and the vibration of the engine **2** gives a considerable stimulus force (approx. 5 G) to the metal carrier **90**. By providing the non-slit parts **94**, however, the resonance frequency of the metal carrier **90** can be improved better than the maximum stimulus frequency (approx. 500 Hz) of the engine **2**.

Consequently, the metal carrier **90** can have a highly durable structure.

The non-slit parts **94**, which are formed both in the flat sheet **91** and in the corrugated sheet **92** in the fourth embodiment, may be formed either in the flat sheet **91** or in the corrugated sheet **92**.

Furthermore, in the fourth embodiment, the slit parts **93** are formed rectangular. However, the present invention is not limited to this shape but may provide the non-slit parts in the roughly rhombic slit parts as illustrated in FIG. **4**, the non-slit part in the corrugated slit parts as illustrated in FIG. **12**, or non-slit parts **98** in ellipsoidal slit parts **97** as illustrated in FIG. **20**.

Moreover, in the fourth embodiment, though the non-slit parts **94** are linear in the fourth embodiment, as illustrated in FIG. **21**, the non-slit parts **99** with enlarged corners is also acceptable.

As described in the above, according to the present invention, a metal carrier for a catalyst converter which is

highly resistant to vibrations and can achieve high and rapid purification performance can be obtained.

Fifth Embodiment

The fifth embodiment according to the present invention will be described.

FIG. 22 is a type view of the metal carrier **110** of the fifth embodiment illustrating the half-wound state.

This metal carrier **110** is composed of an alternating lamination and winding of a flat sheet **111** and a corrugated sheet **112**.

The flat sheet **111** and the corrugated sheet **112** are of Fe-Cr-Al composition with Cr of 18 to 24 wt %, Al of 4.5 to 5.5 wt %, rare earth metal elements (REM) of 0.1 to 0.2 wt % and the rest, Fe, respectively.

The flat sheet **111** and the corrugated sheet **112** are 60 mm wide and 0.03 to 0.20 mm thick respectively. Both the flat sheet **111** and the corrugated sheet **112** are provided with slit parts **115** and **116**, respectively for a width of 30.95 mm at one end side which are different from each other in length-breadth ratio.

FIG. 23 is a fragmentary enlarged view illustrating the shape of the slit parts **115** formed in the flat sheet **111** employed in the fifth embodiment.

FIG. 24 is a fragmentary enlarged view illustrating the shape of the slit parts **116** formed in the corrugated sheet **112** employed in the fifth embodiment.

In FIG. 23, the flat sheet **111** has a slit width **115***a* of 0.55 mm, a slit length **115***b* of 1.1 mm and a slit interval **115***c* of 0.6 mm, and each line of the slit parts **115** is displaced by a half pitch from the adjacent lines thereof with a mesh width **115***d* of 0.4 mm therebetween.

As illustrated in FIG. 24, the flat sheet **112** has a slit width **116***a* of 0.55 mm, a slit length **116***b* of 28 mm and a slit interval **116***c* of 1 mm, and each line of the slit parts **116** is displaced by a half pitch from the adjacent lines thereof with a mesh width **116***d* of 0.4 mm therebetween. Furthermore, non-slit parts **118** of 1 mm wide are provided at every 57 mm to improve the strength, and furthermore, uneven parts are successively formed at a pitch of 4.77 mm and a height of 1.75 mm.

Then, by alternatingly laminating and winding the flat sheet **111** and the corrugated sheet **112**, the metal carrier **110** of the fifth embodiment with a combination of the flat sheet **111** and corrugated sheet **112** with different slit length-breadth ratios as illustrated in FIG. 25 can be obtained.

In this way, in the fifth embodiment, the metal carrier **110** with a combination of the flat sheet **111** with a small slit length-breadth ratio (approx. 1:2) and the corrugated sheet **112** with a large slit length-breadth ratio (approx. 1:50) can be obtained.

Then, the functions of the metal carrier **110** will be described as to a case where the metal carrier **110** is arranged in the exhaust manifolds **3***a* and **3***b*, exhaust gas passages in FIG. 2 illustrating the first embodiment.

After the engine **2** starts, the exhaust gas emitted from each cylinder exhausting process flows through the exhaust manifolds **3***a* and **3***b*, and collides with the slit parts **115** and **116** positioned at the upstream side of the metal carrier **110**.

At this time, the slit parts **116** of the corrugated sheet **112** are less rigid, and, due to slightly displaced pitches and subsequent turbulence effect, efficiently receives heat. Furthermore, due to smaller heat capacity and lower heat conductivity, the temperature of the slit parts **116** of the corrugated sheet **112** rises most rapidly.

Incidentally, the heat conductivity of the slit parts **116** of the fifth embodiment is approx. 1/1000 of the case where no slit parts are provided.

When the temperature of the slit parts **116** reaches the activation temperature of the catalyst held by the metal carrier **110** (about 300° C.), the exhaust gas is begun to be purified, and the catalyst activation is made at the side of the flat sheet **111** and the downstream by the reaction heat and the heat conduction within the metal carrier **110**. In this way, in seconds after the engine **2** starts, the catalyst activation can be made throughout the metal carrier **110**.

On the other hand, the pulsation of the exhaust gas collided with the slit parts **115** and **116** and the vibration of the engine **2** gives a considerable stimulus force (approx. 5 G) to the metal carrier **110**. By setting the slit length-breadth ratio (**115***a*:**115***b*) to a small value, however, the resonance frequency of the metal carrier **110** can be improved better than the maximum stimulus frequency (approx. 500 Hz) of the engine **2**. Consequently, the metal carrier **110** can have a highly durable structure.

In the fifth embodiment, though the slit length-breadth ratio of the flat sheet **111** is set to a smaller value than that of the corrugated sheet **112**, reversely the slit length-breadth ratio of the corrugated sheet **112** may be set to a smaller value than that of the flat sheet **111**.

Moreover, in the fifth embodiment, the non-slit parts **118** are provided on the corrugated sheet **112** with a larger slit length-breadth ratio to prevent the loss in the strength due to the formation of the slit parts **116**. In the fifth embodiment, however, non-slit parts may not be provided as illustrated in FIG. 26, and by not providing non-slit parts, the metal carrier with a higher temperature rise performance can be obtained.

Still more, in the fifth embodiment, though the slit parts **115** and **116** are formed rectangular, the present invention is not limited to this shape but may form the slit parts **115** and **116** roughly rhombic as illustrated in FIG. 4 of the first embodiment, corrugated as illustrated in FIG. 12 or ellipsoidal as illustrated in FIG. 20.

As described in the above, according to the present invention, by differentiating the composition of the slit parts composed of a corrugated sheet and a flat sheet, or specifically by differentiating the length-breadth ratio of the slit parts, the temperature rise characteristics and vibration resistance of the corrugated sheet and flat sheet can be varied. For this reason, a metal carrier which is highly resistant to vibration and can achieve high purification performance in a short time can be obtained.

In the fifth embodiment, though metal carrier **110** is obtained by laminating and winding the flat sheet **111** and the corrugated sheet **112**, the present invention is not limited to this method but may obtain the metal carrier by simply laminating the flat sheet **111** and the corrugated sheet **112**.

Sixth Embodiment

The sixth embodiment relates to the holding method of the metal carriers of the above first to sixth embodiments.

Conventionally, as a catalyst converter for exhaust gas purification, the one as disclosed in the Japanese Examined Patent Publication No. 5-57197, etc. has been known, in which an outer ring, an intermediate tube and a metal carrier are partly connected in the axial direction and a heat insulation materials formed in each non-connected part to control heat radiation at a low temperature and ease thermal stress at a high temperature.

Another one disclosed in the Japanese Utility Model Publication Laid-Open No. 4-53450 has been known, in which the diameter of the downstream side of the exhaust gas passage of an outer ring is made smaller and the outer ring is connected to a metal carrier at this part to ease the thermal stress of the metal carrier.

However, in such a catalyst converter as disclosed in the above Japanese Examined Patent Publication No. 5-57197 or the Japanese Utility Model Publication Laid-Open No. 4-53450, flange structures with a larger heat capacity should be connected to the front and rear parts of the outer ring or the metal carrier itself should be fixed within a housing connected to a flange with a large heat capacity to enable the catalyst converter mounted in the course of the exhaust gas passages of internal combustion engines for vehicles, etc.

At any rate, flange structures, etc. with a large heat capacity should be connected in the vicinity of the upstream of the exhaust gas passages of the outer ring. Therefore, immediately after cold starting in which a large volume of harmful components (HC, CO, NOx) are emitted from the exhaust gas of all times, it takes long to reach the temperature at which the catalyst held by the metal carrier is activated, and sufficient purification can not be expected. What is worse, it takes a heavy cost to manufacture the catalyst converter itself.

The sixth embodiment is to solve the above problems.

Referring to FIGS. 27 through 33, the composition, functions and effects of the sixth embodiment will be described in depth.

FIGS. 27 and 28 illustrates the most typical catalyst converter 120 according to the present invention. FIG. 27 is a cross-sectional view cut across in the direction of exhaust gas flow, and FIG. 28 is a front view illustrating the catalyst converter 120.

In these figures, the numeral 1 denotes the metal carrier of the first embodiment with a plurality of slit parts 9 formed at an end part thereof.

The numeral 121 denotes an outer ring for fixedly holding the metal carrier 1. A space part 122 is provided between the metal carrier 1 and the outer ring 121 at the upstream side of the exhaust gas passage. The metal carrier 1 and the outer ring 121 are connected to each other at one or more connecting points 123 at the downstream side of the exhaust gas passage.

Brim-like flanges 125 both having a small heat capacity is circumferentially connected to the outer periphery of the outer ring 121 at a connecting part 126 within a section in which the space part 122 is provided between the metal carrier 1 and the outer ring 121.

By composing the catalyst converter 120 in the same way as the sixth embodiment for connecting the metal carrier 1 to the outer ring 121 only at the downstream side of the exhaust gas passage (cantilever structure), thermal stress caused in the axial and radial directions can be eased and sufficient durability can be obtained.

The catalyst converter 120 is characterized by comparatively small volume not to disturb the rapid temperature rise and activation of a large-volume catalyst converter which is arranged behind the catalyst converter 120.

The functions of the sixth embodiment will now be described referring to FIGS. 29 and 30.

FIG. 29 is a system view illustrating the catalyst converter 120 as per FIG. 27 mounted in the engine 2. The catalyst converter 120 of the sixth embodiment is arranged within the exhaust manifold 3a.

In addition, the start catalyst 5, a large-volume catalyst converter, is arranged immediately behind the catalyst converter 120.

FIG. 30 is a view enlargingly illustrating the catalyst converter 120 of the sixth embodiment as per FIG. 27 and the start catalyst 5, a large-volume catalyst converter.

In FIG. 30, the catalyst converter 120 is integrally composed with the start catalyst 5 by means of a housing 130 having a flange 131 at the upstream side.

Within this housing 130, with the flange 125 of the catalyst converter 120 via gaskets 132a and 132b caught between an outlet side flange 128 of the exhaust manifold 3a and a flange 131, the catalyst converter 120 is fixedly and held. On the other hand, the start catalyst 5 is fixedly held via a heat insulating material 133 within the housing 130.

Also as illustrated in FIG. 30, the vicinity of the upstream side of the metal carrier 1 is almost coincided in position on the exhaust gas passage with the large-volume outlet side flange 128 of the exhaust manifold 3a.

The functions of the sixth embodiment will further be described.

Immediately after the engine 2 starts, the exhaust gas passes through the exhaust manifold 3a and reaches the upstream side end part of the catalyst converter 120.

At the upstream side end part of the catalyst converter 120, the outer ring 121 and the metal carrier 1 can not directly contact each other due to the space part 122 provided in the catalyst converter 120. For this reason, the quantity of heat which the exhaust gas has can be effectively provided to the vicinity of the upstream end of the metal carrier 1 before being absorbed by the flange 128.

Furthermore, the heat capacity is arranged to be sufficiently small at the upstream side of the metal carrier 1 by means of the slit parts 9 provided at the upstream side of the metal carrier 1, heat is intensively generated in the vicinity of the upstream end of the metal carrier 1. Therefore, the temperature of the catalyst supported by the metal carrier 1 rapidly reaches the activation temperature at which the catalyst can fully exert its purification performance (generally 300° to 350° C. for ternary catalysts).

Then, due to the conduction of the reaction heat generated by the purification reaction of the exhaust gas at the upstream part of the metal carrier 1 to the downstream side thereof, the activation area is rapidly expanded.

As described in the above, after the engine 2 starts, the catalyst converter 120 can rapidly heat the catalyst to the activation temperature throughout the whole area. Moreover, the catalyst converter 120 can efficiently provide a large quantity of reaction heat generated by the purification reaction within the catalyst converter 120 to the large-volume start catalyst 5 for promoting the earlier temperature rise for activation.

In the sixth embodiment, due to the above functions, even under a condition in which a large volume of exhaust gas flows, such as when the engine 2 is in acceleration and the engine 2 is heavily loaded, sufficient purification performance can be secured.

The above effects will be described by using the actual measurement data. FIG. 31 illustrates the measurement positions for the internal temperature of the catalyst converter 120 of the sixth embodiment with the numerals 140 through 143.

FIG. 32 illustrates the results of the measurement.

FIG. 32 illustrates each temperature measurement data ingested immediately after the cold start of the engine 2 after leaving 8 hours in the atmosphere of 25° C.

The temperature in the exhaust gas passage at 140 is measured and the measured data is shown in FIG. 32. The temperature in the vicinity of the upstream end of the exhaust gas passage of the metal carrier 1, identified at 141, rises to the temperature at which the catalyst begun to be activated in seconds after the engine 2 starts, and due to the reaction heat generated by the catalyst reaction, the temperature further rises to exceed 500° C. within 20 seconds. Along with this temperature rise, the temperature of the exhaust gas from the metal carrier 1, identified at 142, also

rises in the same way. Therefore, the temperature in the vicinity of the upstream side of the exhaust gas passage within the start catalyst **5** arranged immediately behind the metal catalyst carrier **1**, identified at **143**, rises to the activation temperature in about 25 seconds after the engine **2** starts. Then, due to the reaction heat of the start catalyst **5**, the activated area rapidly expands towards the downstream side. As a result, even when the engine **2** is in acceleration or heavily loaded under which condition a large volume of exhaust gas flows, sufficient purification performance can be obtained.

Seventh Embodiment

The catalyst converter **150** of the seventh embodiment is illustrated in FIG. **33**.

A metal carrier **151** of this catalyst converter **150** is, as composed in the first embodiment, a corrugated sheet and a flat sheet (both not illustrated) in which slit parts **152**, collectively constituting a low-heat-capacity area, are formed only at the upstream side of the exhaust gas passage, are laminated or wound together.

However, the metal carrier **151** of the seventh embodiment is different from the metal carrier **1** of the first embodiment in that the number of windings of the corrugated sheet and flat sheet at the downstream side of the exhaust gas passage excluding the slit parts **152** is larger than that at the slit parts **152**.

For this difference, the diameter of the metal carrier **151** at the slit parts **152**, collectively constituting the upstream side of the exhaust gas passage, is smaller than that at the part with no slit parts, constituting the downstream side of the exhaust gas passage.

By composing the metal carrier **151**, an outer ring **155** can be so arranged that a space part **153** is provided between the slit parts **152** of the metal carrier **151** and the outer ring **155** without swaging applied to the outer ring **121** of the sixth embodiment to change the diameter thereof.

Furthermore, in the seventh embodiment, the space part **153** formed between the slit parts **152** of the metal carrier **151** and the outer ring **155** is shorter in the axial direction that of the sixth embodiment.

On the other hand, the outer ring **155** is connected to the metal carrier **151** only at the place where the slit parts **152**, constituting the downstream side of the exhaust gas passage of the metal carrier **151**, are not formed, and a flange **156** is provided to the upstream side end part of the exhaust gas passage of the outer ring **155**.

FIG. **34** illustrates the composition with the catalyst converter **150** of the seventh embodiment is arranged within the exhaust gas passage.

As illustrated in FIG. **34**, also in the seventh embodiment, the catalyst converter **150** is fixedly held within the exhaust gas passage with the flange **156** of the outer ring **155** caught between the outlet side flange **128** and the flange **131** via the gaskets **132***a* and **132***b*.

By fixedly holding the catalyst converter **150** in the above way, a space part **157** is formed between the metal carrier **151** and the exhaust manifold **3***a*.

According to the above arrangement, by shortening the distance of the space part **153** in the axial direction than that of the sixth embodiment, the slit parts **152** formed at the upstream side of the exhaust gas passage of the metal carrier **151** can be positioned at the upstream side from the large-heat-capacity outlet side flange **128** of the above exhaust manifold **3***a*.

As a result, at the temperature rise time in the slit parts **152** of the metal carrier **151**, the heat shrink of the metal carrier **151** can not easily be caused due to the large-heat-capacity flange **128**.

Eighth Embodiment

The catalyst converter **160** of the eighth embodiment is illustrated in FIG. **35**. As composed in the first embodiment, a metal carrier **161** composing the catalyst converter **160** of the eighth embodiment is composed of a lamination and winding of flat sheet and a corrugated sheet (both not illustrated) with slit parts **162** formed at the upstream side of the exhaust gas passage.

The metal carrier **161** is connected to an outer ring **165** at the downstream side of the exhaust gas passage where the slit parts **162** are not formed. A space **167** is provided between metal carrier **161** and exhaust manifold **3***a* at the upstream side of the exhaust gas passages where the slit parts **162** are formed.

The eighth embodiment is different from the sixth embodiment in that any space part is not provided between the outer ring **165** and the metal carrier **161**. The composition of the catalyst converter **160** arranged within the exhaust gas passage is illustrated in FIG. **36**. As illustrated in FIG. **36**, also in the eighth embodiment, the catalyst converter **160** is fixedly held within the exhaust gas passage with a flange **166** provided on an outer ring **165** caught between the outlet side flange **128** and the flange **131** via the gaskets **132***a* and **132***b*.

According to the above arrangement, in the same way as the seventh embodiment, the slit parts **162** formed at the upstream side of the exhaust gas passage of the metal carrier **161** can be positioned at the upstream side from the large-heat-capacity outlet side flange **128** of the above exhaust manifold **3***a*.

As a result, at the temperature rise time in the slit parts **162** of the metal carrier **161**, the heat shrink of the metal carrier **161** can not easily be caused due to the large-heat-capacity flange **128**.

This can improve the temperature rise characteristics of the metal carrier **161**.

By employing the sixth, seventh or eighth embodiment, the upstream side part of the exhaust gas passage of the metal carrier can control the heat radiation in the radial direction due to the heat insulation effect of the air layer provided between the outer surface of the metal carrier and the inner surface of the outer ring.

Furthermore, due to no large-heat-capacity flange structure for arranging the catalyst converter body in some place within the exhaust gas passage, the temperature of the catalyst can rapidly be raised to the activation temperature at which the catalyst can exert the sufficient purification performance immediately after the cold start of the engine **2** in particular. Also in the eighth embodiment, the metal carrier may be obtained by only laminating a flat sheet and a corrugated sheet.

Ninth Embodiment

In the catalyst converter **120** of the sixth embodiment, the connection of the metal carrier **1** and the outer ring **121** is made at an end part of the metal carrier **1** where the slit parts **9** of the metal carrier **1** are not formed.

According to this arrangement, the conduction of the heat received by the slit parts **9** of the metal carrier **1** can be checked on the way from the metal carrier **1** to the outer ring **121** by forming the space part **122**.

However, this arrangement of connecting the outer ring **121** to the metal carrier **1** at an end part is equivalent to cantilevering the metal carrier **1**.

The catalyst converter **120** arranged within the exhaust gas passage is easily affected by vibration, etc, when the applied vehicle is in traveling due to this cantilevering of the metal carrier **1**, causing problems, such as the breakage of the metal carrier **1** and incomplete holding back of the metal carrier **1**.

Furthermore, the metal carrier 1 itself is heated to a high temperature due to the catalyst reaction with the exhaust gas, and the allowable stress of the material of the outer ring 121 is sharply reduced. As a result, the catalyst converter 120 is easily affected by the vibration, etc. when the applied vehicle is in travelling.

In order to solve these problems, it is necessary to minimize the force applied to the connecting points between the outer ring 121 and the metal carrier 1.

Accordingly, it is a primary object of the ninth embodiment to reduce the force applied to the connecting points of the metal carrier 1 and the outer ring 121.

FIG. 37 is a cross-sectional view illustrating the catalyst converter 170 of the ninth embodiment cut across in the axial direction. As composed in the first embodiment, the metal carrier 1 of the ninth embodiment is composed of an alternating winding of a flat sheet and a corrugated sheet both with slit parts 9 at one side.

In this ninth embodiment, the metal carrier 1 and the outer ring 121 are connected at more than one connecting points. The ninth embodiment is characterized by the position of these connecting points 175.

Specifically, the ninth embodiment is characterized by the connecting points 175 which are provided in the vicinity of a line b perpendicular at the center of gravity 177 of the metal carrier 1 to the axial line a of the metal carrier 1 passing through the center of gravity.

By setting the contact points 175 to the specified positions, the load applied on the contact points due to cantilevering the metal carrier 1 can be eliminated. As a result, the damage to and incomplete holding back of the metal carrier 1 due to vibration, etc. when the applied vehicle is in travelling, can be controlled, and durability to such vibration, etc. can be improved.

In addition, by adjusting the width of the slit parts 9 formed in the metal carrier 1 and shifting the center of gravity of the metal carrier 1 to any position, the positions of these contact points 175 can also be freely adjusted.

In the ninth embodiment, by providing slit parts as a small-heat-capacity area, the center of gravity of the metal carrier 1 can be shifted to the downstream side of the exhaust gas passage of the metal carrier 1.

FIGS. 38 and 39 illustrate other embodiment according to the present invention. As illustrated in FIG. 38, the center of gravity of a metal carrier 178 may be shifted backwards by shortening either a corrugated sheet or a flat sheet both composing the metal carrier 178 to form a low-heat-capacity area.

Furthermore, as illustrated in FIG. 39, the center of gravity of the metal carrier 178 may be shifted backwards by thinning either side of a metal sheet 179, either corrugated or flat, to form a low-heat-capacity area.

Also in the ninth embodiment, the metal carrier 1 may be formed only by alternatingly laminating the flat sheet and the corrugated sheet.

Tenth Embodiment

In the sixth embodiment, the catalyst converter 120 is composed of the metal carrier 1 and the outer ring 121.

For application to the sixth embodiment, the metal carrier 1 and the outer ring 121 may be fixedly connected to each other by forced fitting. When the outer ring 121 is forcedly fit over the metal carrier 1, a problem may be caused that the metal carrier 1 is deformed by the friction force generated between the most outer periphery of the metal catalyst carrier 1 and the inner periphery of the outer ring 121.

Accordingly, it is the primary object of the tenth embodiment to prevent the deformation of the metal carrier 1 in such forced fitting.

The tenth embodiment will be described referring to FIG. 40 through 43. FIGS. 40 and 41 illustrate the configuration of the catalyst converter 185 of the tenth embodiment.

Here, FIG. 40 is a cross-sectional view illustrating the catalyst converter 185 of the tenth embodiment cut across in the axial direction, and FIG. 41 is a front view illustrating the catalyst converter 185.

The catalyst converter 185 is composed of a metal catalyst carrier 187 and an outer ring 189 for fixedly holding back this metal carrier 187.

The metal carrier 187 is composed of an alternating winding of a corrugated sheet 191 and a flat sheet 192 both with slit parts 190 formed at one end side. The corrugated sheet 191 and the flat sheet 192 are connected by means of laser welding, etc. at the end part in the axial direction.

The metal carrier 187 is so arranged that the corrugated sheet 191 and the flat sheet 192 are wound together so that the corrugated sheet 191 defines the most outer periphery along only a portion of the metal carrier 187 and is in contact with the outer ring 189.

That is, by forcedly fitting the outer ring 189 over the most outer periphery of the corrugated sheet 191, the metal carrier 187 and the outer ring 189 are forcedly fixed each other. Furthermore, the metal carrier 187 and the outer ring 189 are connected by means of laser welding, etc. at the downstream side in the axial direction of the metal carrier 187.

At the upstream side of the metal carrier 187 in the axial direction, where the slit parts 190 are formed, a space part 194 is formed between the outer periphery of the metal carrier 187 and the outer ring 189 connected to the metal carrier 187 only at one end part.

The tenth embodiment is characterized by the method of connecting the metal carrier 187 and the outer ring 189, which will be further described referring to FIG. 42.

The corrugated sheet 191 is wound around the most outer periphery of the metal carrier 187 at the end part of the downstream side. The outside diameter of the metal carrier 187 is set to be equal to or slightly larger than the inside diameter of the outer ring 189. When the outer ring 189 is forcedly fit over the corrugated sheet 191 which constitutes the connecting part only at the downstream part in the axial direction, an end side of the metal carrier 187, the metal carrier 187 and the outer ring 189 are fixed.

When the outer ring 189 is forcedly fixed over the metal carrier 187, a radially shrinking force Fr is caused to the corrugated sheet 191 constituting the most outer periphery and the outer ring 189 and a friction force μFr is caused to between the corrugated sheet 191 constituting the most outer periphery of the metal carrier 187 and the outer ring 189. Therefore, as illustrated in FIG. 42, at an end part of the outer ring 189, the resultant force F of the radial shrinking force Fr and the friction force μFr acts on the honeycomb catalyst carrier 187.

Furthermore, as the friction force μFr intensively acts on the interface between the corrugated sheet 191 constituting the most outer periphery of the metal carrier 187 and the outer ring 189, the resultant force F caused to the metal carrier 187 is the largest when the outer ring 189 is forcedly fix over the metal carrier 187.

Compared with the outer ring 189, the metal carrier 187 is smaller in wall thickness and lower in rigidity due to the reason of its own structure. What is more, the corrugated sheet 191 is formed on the most outer periphery of the metal carrier 187 at the connecting surface between the metal carrier 187 and the outer ring 189, and the corrugated sheet 191 is welded to the flat sheet 192 only at the inner periphery thereof. Therefore, when friction force is applied from the outside, the corrugated sheet 191 may easily be deformed.

Consequently, as illustrated in FIG. 43, when the outer ring 189 is forcedly fit over the metal carrier 187, the corrugated sheet 191 of the most outer periphery, which is a part most likely to be deformed of all the parts of the metal carrier 187, is deformed first of all.

The resultant force F of the radial shrinking force Fr and the friction force μFr is absorbed by the deformation of the corrugated sheet 191, and, as a result, the stress working on the entirety of the metal carrier 187 can be reduced.

After the outer ring 189 is forcedly fit over the metal carrier 187, the outer ring 189 and the metal carrier 187 are connected by means of laser welding, etc. at the most outer periphery of the deformed corrugated sheet part 191.

At this time, the most outer periphery of the corrugated sheet 191, which is coincided with the connecting part of the metal carrier 187 and the outer ring 189 and deformed first of all in the force fitting, has a larger area to contact the outer ring due to the deformation.

For this reason, the metal carrier 187 and the outer ring 189 can have an increased contact area and consequently better welding condition.

As a result, the mechanical strength and durability of the catalyst converter 135 can be improved.

In the tenth embodiment, the diameter of the outer ring 189 at the end part corresponding to the slit parts 190 of the metal carrier 187 is larger than the diameter of the other end part. However, the tenth embodiment is not limited to this arrangement but may be simply tubular as an outer ring 195 illustrated in FIG. 44 for example.

Furthermore, the shape like an outer ring 197 illustrated in FIG. 45, for example, is also acceptable.

What is more, in the above description, the most outer periphery is the corrugated sheet 191 only at the interface of the metal carrier 187 and outer ring 189. However, the tenth embodiment is not limited to this arrangement but may be so arranged as illustrated in FIG. 46 that all the most outer periphery of the metal carrier 199 is a corrugated sheet 200 and a tubular outer ring 201 is forcedly fit over the metal carrier 199.

When all the outer periphery of the metal carrier is composed of one corrugated sheet 200, the most outer periphery of the metal carrier 199 over which the outer ring 201 is not forcedly fit is also subject to the effects of the deformation of the corrugated sheet 200 over which the outer ring 201 is forcedly fit.

Therefore, as illustrated in FIG. 47, the tenth embodiment may be so arranged that a metal carrier 204 is alternatingly wound by a flat sheet and a corrugated sheet and then only the most outer periphery of the corrugated sheet of the metal carrier 204 is provided with a cutout part 206*a*.

By providing the cutout part 206*a* only to the most outer periphery of the corrugated sheet 206 in the above way, the effects of the deformation caused to the corrugated sheet when the outer ring 208 is forcedly fit thereover to the most outer periphery of the corrugated sheet can be prevented.

Furthermore, the shape of the cutout part is not limited to the one which extends all over the most outer periphery of the corrugated sheet 206, but may elongate only the last slits of the slit parts such as the one 209 illustrated in FIG. 48.

Moreover, as illustrated in FIG. 49, the cutout part 210 may be shaped by elongating the last few lines of slits may be increasingly elongated.

Also, the metal carrier may be composed only of a lamination of the flat sheet and the corrugated sheet.

Eleventh Embodiment

In the sixth embodiment, it is proposed that the outer ring 121 should be provided, which is connected to the most outer periphery of the metal carrier 1 at the downstream side in the axial direction of the metal carrier 1 which includes the slit parts at the upstream side in the axial direction thereof.

In such arrangement, the connection of the metal carrier 1 and outer ring 121 is achieved by apply welding to a plurality of spots. In such arrangement, however, it is difficult to simultaneously apply welding to all the connecting places, and therefore, welding should be applied to each spot one by one or to a group of places group by group.

Here, possible problems with this welding method will be described referring to FIGS. 52A and 52B.

FIG. 52A is a schematic rear view illustrating the condition of the catalyst converter with the metal carrier 1 and the outer ring 121 forcedly fit over the metal carrier 1 but not yet welded. FIG. 52B is also a schematic rear view illustrating the condition of the catalyst converter with the metal carrier 1 and the outer ring 121 forcedly fit over the metal carrier 1 and welded at one spot.

As illustrated in FIG. 52A, the catalyst converter is in good condition with no clearance between the metal carrier 1 and the outer ring 121 before welding. After applying welding at one spot, however, the welded spot is heated to near the melting point of each material of the outer ring 121 and the metal carrier 1, and, as a result, the outer ring 121 sustains thermal deformation and thermal strain. This causes troubles, such as clearance between the outer ring 121 and the metal carrier 1 at the welded spot, and defective welding may be caused, and it is difficult to obtain good welding strength.

Accordingly, it is the primary object of the eleventh embodiment to reduce the effects of the thermal deformation at the welded parts on the other welded parts and obtain good welding strength by providing cutouts at the rear part of the metal carrier 1 in the axal direction from the rear end in the axial direction.

FIG. 50 illustrates the cross-sectional view of the catalyst converter 210 of the eleventh embodiment cut across in the axial direction. FIG. 51 illustrates a rough rear view of the catalyst converter 210.

The catalyst converter 210 is composed of the metal carrier 1 described in the description of the first embodiment and an outer ring 212 for fixedly holding back the metal carrier 1.

The eleventh embodiment is characterized by the shape of the outer ring 212.

The outer ring 212 is cylindrical, and connected to the metal carrier 1 at the downstream side in the axial direction where the slit parts 9 are not formed. Particularly, the side where this outer ring 212 is connected to the metal carrier 1 includes strip parts 216.

The outer ring 212 is forcedly fit over the metal carrier 1 at the downstream side of the metal carrier 1 in the axial direction. Subsequently, the metal carrier 1 and the outer ring 212 are welded by means of laser welding, etc. at welding places 218 which are coincident with the end part of the downstream side of the strip parts 216 in the axial direction.

At this time, the welding places 218 may be continuous in the radial direction, and the welding method is not limited to laser welding.

The functions of the eleventh embodiment will now be described. The eleventh embodiment is characterized by providing the strip parts 216 by forming the cutout parts 214 in the outer ring 212.

By arranging like the above, the outer ring 212 can be selectively welded to the metal carrier 1 at any strip parts

216. That is, by providing free welding places, the holding strength of the metal carrier 1 can be adjusted to any level.

As illustrated in FIG. 50, the welding spots 218 should preferably be provided at the downstream side of the strip parts 216 in the axial direction. In this arrangement, the heat conduction distance between the mutual strip parts 216 of the outer ring 212 can be extended, and whereby the effects of the thermal stress and thermal strain caused by welding may be checked.

However, as the width of these cutout parts 214, c (FIG. 53), may cause gas leakage, the width c should preferably be minimized.

Furthermore, in the eleventh embodiment, the strip parts 216 are formed at the outer ring 212, and these strip parts 216 are of cantilever structure. For this structure, the metal carrier 1 can be fixedly held by taking advantage of the deflection of the strip parts 216.

In addition, as the outer ring 212 can be welded to the metal carrier 1 while being pressed against the metal carrier, stable and good welded parts can be obtained.

Incidentally, for effective utilization of the deflection of the strip parts 216, the length of the strip parts 216, b, should preferably be equal to or larger than a (FIG. 53).

What is more, when the metal carrier 1 is forcedly fit into the outer ring 212, the strip parts 216 of the outer ring 212 deflects. This deflection generates pressing force against the metal carrier 1, and whereby good welded places of the metal carrier 1 and outer ring 212 can be obtained.

In the above embodiment, though the cutout parts 214 are simply shaped into slits, the cutout parts 214 is not limited to this shape but may be composed as illustrated in FIGS. 54 through 56. Incidentally, in FIG. 56, though cutouts extend askew with respect to the axial direction, the cutouts may be curved with respect to the axial direction.

In FIG. 57, cutouts 222 are formed at the root parts of the strip parts 220 in the thickness direction. This arrangement can also obtain the same effects as the above.

Twelfth Embodiment

In the sixth embodiment, the catalyst converter 120 is obtained by forcedly fitting the metal carrier 1 into the outer ring 121 and then welding the metal carrier 1 to the outer ring 121. At this time, the outer ring 121 is provided with the flange 125 for fixing the catalyst converter 120 within the housing 130.

In the twelfth embodiment, however, a method of fixing the catalyst converter 120 within the housing 130 without providing a flange on the outer ring 232 will be described.

The catalyst converter 230 of the twelfth embodiment is illustrated in FIG. 58. In FIG. 58, numeral 5 denotes a start catalyst fixed within the housing 130. The catalyst converter 230 of the twelfth embodiment is composed of the metal carrier 1 which is formed by an alternating winding of a flat sheet and a corrugated sheet and a flangeless outer ring 232.

Both the flat sheet and corrugated sheet of the metal carrier 1 are provided with the slit parts 9 at the upstream side of the exhaust gas passage of the metal carrier 1 as described in the description of the sixth embodiment.

On the other hand, at the downstream side of the exhaust gas passage of the metal carrier 1, the outer ring 232 is connected to the metal carrier 1 by welding at the connecting places 234.

Furthermore, at the upstream side of the exhaust gas passage of the outer ring 232, the outer ring 232 is in opposition to the metal carrier 1 with a space part 233 therebetween.

The outer ring 232 and the housing 130 are connected to each other within the range in the axial direction where the space part 233 is formed at one or more the connecting points 236 on the inner wall of the housing 130 and the outer surface of the outer ring 232 by applying completely circumferential welding or partial welding.

That is, the catalyst converter 230 is fixed within the housing 130 at the connecting parts 236.

Now, the functions of the space parts 233 provided particularly at the upstream side of the exhaust gas passage between the metal carrier 1 and the outer ring 232 will be described.

By providing the space part 233, the heat generated in welding the housing 130 and the outer ring 232 passes through outer ring 232 and reaches the metal carrier 1.

For example, when the outer ring 232 is connected to the housing 130 by welding, the welding heat can not directly affect the metal carrier 1 by providing the space part 233. Therefore, the catalyst held by the metal carrier can be protected from damage and degradation in the welding process.

Furthermore, as the catalyst converter 230 can be welded to the housing 130, the catalyst converter 230 can easily be positioned with respect to the housing 130.

Moreover, as there is no need to provide any flange to the outer ring 232, the number of parts can be reduced.

In addition to the above, the space part 233 can control heat radiation from the metal carrier 1 in the radial direction when applied to actual vehicles, and rapid temperature rise and activation in cold starting can be achieved.

Thirteenth Embodiment

FIG. 59 illustrates the catalyst converter 240 of the thirteenth embodiment. In a catalyst converter 240 of the thirteenth embodiment, a heat insulation layer is formed by providing a heat insulation material 242 in a space formed between the metal carrier 1 and outer ring 232 of the catalyst converter 240 of the twelfth embodiment.

The heat insulation material 242 is provided on part of or the whole of the outer periphery of the slit parts 9 of the metal carrier 1.

By providing the heat insulation material 242, the direct conduction of the heat generated by welding at the connecting places 244 of the outer ring 232 and housing 130 to the metal carrier 1 can be prevented.

Furthermore, the vibration due to the cantilevering of the metal carrier 1 caused by vibration when applied to vehicles can be controlled, and consequently the durability of the metal carrier 1 can be improved.

Fourteenth Embodiment

In FIG. 58, by reducing the diameter of the outer ring 232 at the downstream side of the exhaust gas passage, the space part 233 is provided between the outer ring 232 and the metal carrier 1.

As is the case with the metal carrier 246 illustrated in FIG. 60, however, compared with the diameter of the metal carrier 246 where slit parts 248 are formed, the diameter thereof where the slit part 248 are not formed may be arranged larger.

At the side where the slit parts 248 are not formed, the metal carrier 246 is forcedly fix into an outer ring 249 and then welded thereto. As a result, a space part 252 is formed between the outer ring 249 and the metal carrier 246 by the difference in diameter between the part where the slit parts 248 are formed and the part where the slip part 248 are not formed.

As described in the above, a space part 252 may be provided by making the outer ring 249 simply cylindrical and the shape of the metal carrier 246 changed.

That is, it may be so arranged that, in welding the metal carrier to the flange of the outer ring, the welding heat can be prevented from conducting to the metal carrier.

As described in the above, in the twelfth, thirteenth and fourteenth embodiments, the space part or the insulating material is provided between the metal carrier and the outer ring.

Fifteenth Embodiment

FIG. 61 is a cross-sectional view illustrating the catalyst converter **250** of the fifteenth embodiment.

The catalyst converter **250** is composed of a metal carrier **251**, an outer rings **256** and **257** for fixedly holding back the metal carrier **251**, and a ring **258** for fixing the outer rings **256** and **257**.

The metal carrier **251** is an iron (Fe) based alloy and a ferrite type heat resistant steel including of chrome (Cr,18 to 24 wt %), aluminum (Al, 4.5 to 5.5 wt %) and rare earth metal elements (REM, 0.1 to 0.2 wt %). The metal carrier **251** is formed into honeycomb by alternatingly winding one or more pairs of a flat sheet **252** of several μm in thickness and a corrugated sheet **254** shaped into corrugation from the flat sheet **252**. Furthermore, the flat sheet **252** and the corrugated sheet **254** adjacent to each other are connected to each other by means of brazing, resistance welding, laser welding or electrical discharge welding. The metal carrier **251** is provided with catalyst holdback by means of γ-coat or other and catalyst purification ability.

Next, the outer rings **256** and **257** and the ring **258**, which are characteristic parts of the fifteenth embodiment, will be described.

The outer rings **256** and **257** for covering the metal carrier **1** are of split structure.

Furthermore, the outer rings **256** and **257** are provided with step parts **256*a*** and **257*a***. By forming these step parts **256*a*** and **257*a***, the metal carrier **251** and the outer rings **256** and **257** contact the outer periphery of the metal carrier **251** only at one side of the metal carrier **251**, and the other side of the outer periphery of the metal carrier **251** forms a space part **259** with the outer rings **256** and **257**.

The outer rings **256** and **257** are fixedly connected to the metal carrier **251** by means of laser welding or brazing.

The split outer rings **256** and **257** are fixed by the ring **258** which is set on the outer periphery of the split outer rings **256** and **257** in contact with the step parts **256*a*** and **257*a***.

In the fifteenth embodiment, the inside diameter of the ring **258** is set to be equal to or slightly smaller than the outside diameter which is formed by coupling the split outer rings **256** and **257**. Therefore, the outer rings **256** and **257** can be firmly fixed by the ring **258**.

Furthermore, the outer rings **256** and **257** are fixed further strongly by means of welding applied to the end surfaces of the outer rings **256** and **257** and the inner periphery of the ring **258**.

In the above arrangement, the metal carrier **251**, the outer rings **256** and **257** and the ring **258** are integrally combined to form the catalyst converter **250**.

On the other hand, welding to be applied to the outer rings **256** and **257** and the ring **258** may be arc welding or laser welding. Furthermore, the clearance between the two pieces of the split outer rings **256** and **257** is closed by means of welding or other.

As the metal carrier **251** is disposed between the outer rings **256** and **257** and then the ring **258** is forcedly fit on the outer rings **256** and **257** from the outer periphery, the positioning of the metal carrier **251** with respect to the outer rings **256** and **257** and the fixation of the metal carrier **251** to the outer rings **256** and **257** at the same time, and therefore, the catalyst converter **250** can easily be obtained.

Moreover, by forming the step parts **256*a*** and **257*a*** on the outer rings **256** and **257**, the ring **258** can easily be positioned.

What is more, by splitting the outer ring into the outer rings **256** and **257**, the metal carrier **251** can easily be housed within the outer rings **256** and **257** without applying an extra shrinking stress, such as forcedly fitting. For this reason, the durability of the metal carrier **251** can be improved.

Still more, as the positioning of the metal carrier **251** with respect to the outer rings **256** and **267** can easily be made, the housing of the metal carrier **251** can easily be made, as well.

In addition, the ring **258** for the catalyst converter **250** may also be used as a flange.

Specifically, as illustrated in FIG. 62, the ring **258** may be placed in some place between exhaust manifolds **262** and **264** or in front of another catalyst converter (not illustrated). By arranging in this way, the catalyst converter **250** of the fifteenth embodiment can be installed without changing the composition of the exhaust manifolds **262** and **264** and another catalyst converter.

Sixteenth Embodiment

In the fifteenth embodiment, the outer rings composing the catalyst converter **250** are composed of the upper and lower split outer rings **256** and **257**, and the clearance between the split outer rings **256** and **257** is closed by welding or other means.

However, in the sixteenth embodiment, this clearance is slightly left. The catalyst converter **270** of the sixteenth embodiment is illustrated in FIG. 63.

In the catalyst converter **270**, a clearance part **275** is formed at the connecting surface of outer rings **272** and **274** for fixedly holding back the metal carrier **251**.

This clearance part **275** is formed to such an extent that the gas including the exhaust gas passing through the catalyst converter **270** can not be leaked from the clearance part **275** when such gas passes therethrough.

Then, these outer rings **272** and **274** are fixed by a ring **276**.

According to the sixteenth embodiment, when the reaction heat is generated by the catalyst held by the metal carrier **251** when high-temperature gas, such as exhaust gas, flows into the metal carrier **251**, and even if, for example, the metal carrier **251** sustains thermal expansion, the thermal stress caused between the metal carrier **251** and the outer rings **272** and **274** can be reduced by forming the clearance part **275** between the outer rings **272** and **274** so that the clearance part **275** can be push apart wider.

Furthermore, in fixing the metal carrier **251** to the outer rings **272** and **274** by welding, the clearance or deformation to be caused by welding strain can be prevented, and problems, such as defective welding, can be solved.

In the fifteenth and sixteenth embodiments, though the ring is used for the fixation to the exhaust manifold, direct welding to the exhaust manifold may be employed instead or a flange-like ring may be formed at both ends.

In addition, in the above embodiments, the metal carrier is obtained by alternatingly winding the flat sheet and the corrugated sheet. However, these embodiments are not limited to this method but the metal carrier may be of lamination type simply laminating the flat sheet and the corrugated sheet alternatingly.

Moreover, for the metal carrier according to the fifteenth and sixteenth embodiments, the metal carrier **1** described in the description of the first embodiment may be employed, and the metal carrier **187** according to the tenth embodiment may also be employed.

In the above first to sixteenth embodiments, it is so arranged that the temperature of the metal carrier according to the present invention is rapidly be raised by not electri-

cally continuing the metal carrier to promote the activation of the catalyst.

However, the metal carrier according to the present invention is not to be employed only for the catalyst converter which is to be used without electrically continuing, but may be so arranged that the metal carrier is electrically continued to be better catalyst converter with better temperature rise characteristics.

Specifically, the metal carrier may be electrically continued from the downstream side of the exhaust gas passage to the upstream side thereof.

What is claimed is:

1. A metal carrier for cleaning an exhaust gas and arranged in the course of an exhaust gas passage of an internal combustion engine, comprising:

at least one flat metal sheet; and

at least one corrugated metal sheet superimposed with said flat metal sheet one over the other and defining a plurality of axial gas passages to allow an exhaust gas to flow axially from an upstream side to a downstream side of said gas passages, said flat metal sheet and said corrugated metal sheet each having an upstream portion and a downstream portion;

wherein both said flat metal sheet and said corrugated metal sheet have slit parts formed from through-holes which are defined solely in said upstream portions of said flat sheet and of said corrugated sheet.

2. The metal carrier according to claim 1, wherein at least one of said flat metal sheet and said corrugated metal sheet holds a catalyst thereon.

3. The metal carrier according to claim 2, wherein said through-holes formed in said flat sheet are different in shape from said through-holes formed in said corrugated sheet.

4. The metal carrier according to claim 1, wherein at least one of said flat sheet and said corrugated sheet has non-slit parts in which no slits have been formed, at said the upstream side of said gas passages and which extends along said gas passages.

5. The metal carrier according to claim 1, wherein the flat sheet and the corrugated sheet are wound together so that said corrugated sheet defines an outerperiphery of said metal carrier.

6. A catalytic converter for cleaning an exhaust gas and arranged in the course of an exhaust gas passage of an internal combustion engine, comprising:

a metal carrier including:

at least one flat metal sheet; and

at least one corrugated metal sheet superimposed with said flat metal sheet one over the other and defining a plurality of axial gas passages to allow an exhaust gas to flow axially from an upstream side to a downstream side of said gas passages, said flat metal sheet and said corrugated metal sheet each having an upstream portion and a downstream portion;

wherein both said flat metal sheet and said corrugated sheet have slit parts formed from through-holes which are defined solely in said upstream portions of said flat sheet and of said corrugated sheet; and

an outer ring for fixedly holding said metal carrier, said outer ring connecting with said metal carrier at the downstream side of said gas passages and having a space with said metal carrier at the upstream side of said gas passages.

7. The catalytic converter according to claim 6, further comprising an insulation material disposed in said space between said metal carrier and said outer ring.

8. The catalytic converter according to claim 6, wherein the flat sheet and the corrugated sheet are wound together so that said corrugated sheet defines an outerperiphery of said metal carrier.

9. The catalytic converter according to claim 6, wherein said outer ring is divided into at least two parts along an axis of said metal carrier.

10. The catalytic converter according to claim 6, wherein said outer ring has slit parts formed from through-holes at one end thereof.

11. The catalytic converter according to claim 9, wherein said outer ring has a flange extending perpendicularly to the axis of said metal carrier and formed at an outerperiphery of said outer ring for mounting to an exhaust gas passage.

12. A metal carrier for cleaning an exhaust gas and arranged in the course of an exhaust gas passage of an internal combustion engine, comprising:

at least one flat metal sheet; and

at least one corrugated metal sheet superimposed with said flat metal sheet one over the other and defining a plurality of axial gas passages to allow an exhaust gas to flow axially from an upstream side to a downstream side of said gas passages; said flat metal sheet and said corrugated metal sheet each having an upstream portion and a downstream portion;

wherein both said flat metal sheet and said corrugated metal sheet have slit parts formed from through-holes which are defined solely in said upstream portion of said flat sheet and of said corrugated sheet, said through-holes being disposed in an area limited to about 18% to 52% of the width of said two metal sheets.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 5,648,050
DATED : JULY 15, 1997
INVENTOR(S) : MATSUMOTO ET AL

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

ON THE TITLE PAGE:

Item: [30] Foreign Application Priority Data
Dec. 24, 1993 [JP] Japan ....5-350447"

should be

--[30] Foreign Application Priority Data
Dec. 27, 1993 [JP] Japan 5-350447--

Signed and Sealed this

Twenty-seventh Day of January, 1998

Attest:

BRUCE LEHMAN

Attesting Officer

Commissioner of Patents and Trademarks

US005599509A

United States Patent [19]

Toyao et al.

[11] **Patent Number: 5,599,509**

[45] **Date of Patent: *Feb. 4, 1997**

[54] **HONEYCOMB BODY AND CATALYST CONVERTER HAVING CATALYST CARRIER CONFIGURED OF THIS HONEYCOMB**

[75] Inventors: **Tetsuya Toyao**, Toyoake; **Toshiki Matsumoto**, Kariya; **Hiromasa Aoki**, Nagoya; **Tatsuya Fujita**; **Senta Tojo**, both of Kariya, all of Japan

[73] Assignee: **Nippondenso Co., Ltd.**, Kariya, Japan

[*] Notice: The portion of the term of this patent subsequent to Mar. 16, 2014, has been disclaimed.

[21] Appl. No.: **416,578**

[22] Filed: **Apr. 4, 1995**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 213,806, Mar. 16, 1994.

[30] **Foreign Application Priority Data**

Mar. 17, 1993	[JP]	Japan	5-56908
Dec. 27, 1993	[JP]	Japan	5-350447
Oct. 4, 1994	[JP]	Japan	6-240231

[51] **Int. Cl.**^{6} **B01D 53/34**; B01J 35/04; F01N 3/10

[52] **U.S. Cl.** **422/180**; 422/177; 422/179; 422/211; 422/221; 422/282; 60/297; 502/439; 502/527

[58] **Field of Search** 422/169–170, 422/177, 179, 180, 211, 221, 222; 502/439, 527; 428/593; 60/299

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92/13635	8/1992	WIPO .

Primary Examiner—Robert J. Warden
Assistant Examiner—Hien Tran
Attorney, Agent, or Firm—Cushman Darby & Cushman IP Group of Pillsbury Madison & Sutro LLP

[57] **ABSTRACT**

In a metal catalyst converter configured of the metal catalyst carrier that holds the catalyst into the honeycomb body created by alternately winding flat sheet and corrugated sheet, a plurality of slit matrix that extend in the direction perpendicular to the exhaust gas direction were arranged on at least one part of the upstream side of the exhaust gas passage. By that a low heat capacity and high heat transfer area in regard to the downstream side of the exhaust gas passage was formed. The upstream portion of the metal catalyst converter on which slit matrix was formed was configured to be covered by outer casing having an air insulation layer. The upstream side of this outer casing was held and fixed to the exhaust gas passage.

28 Claims, 26 Drawing Sheets

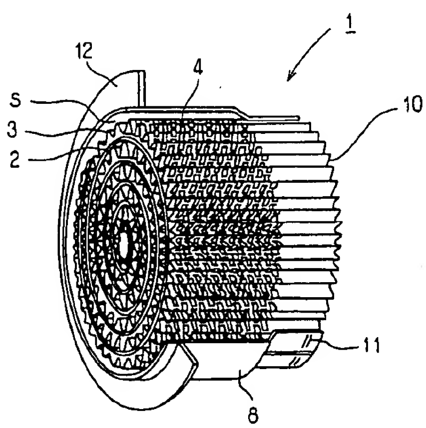


FIG. 1

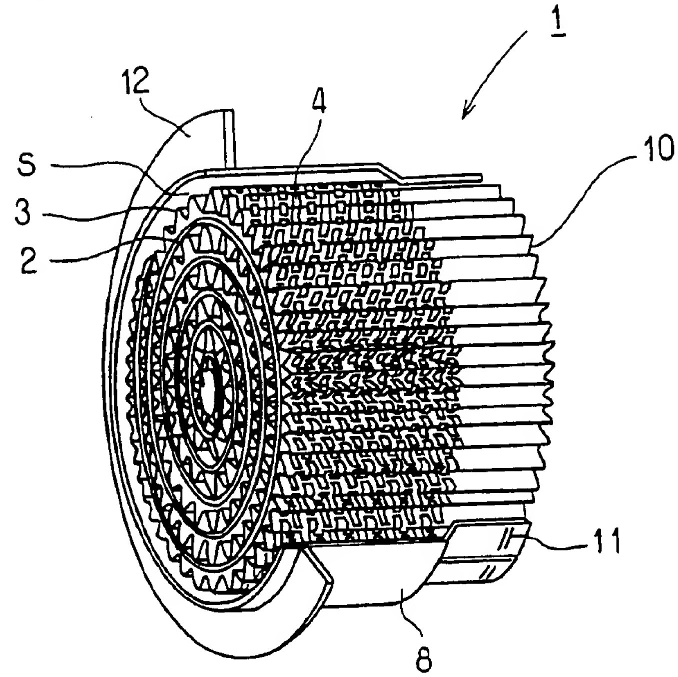


FIG. 2

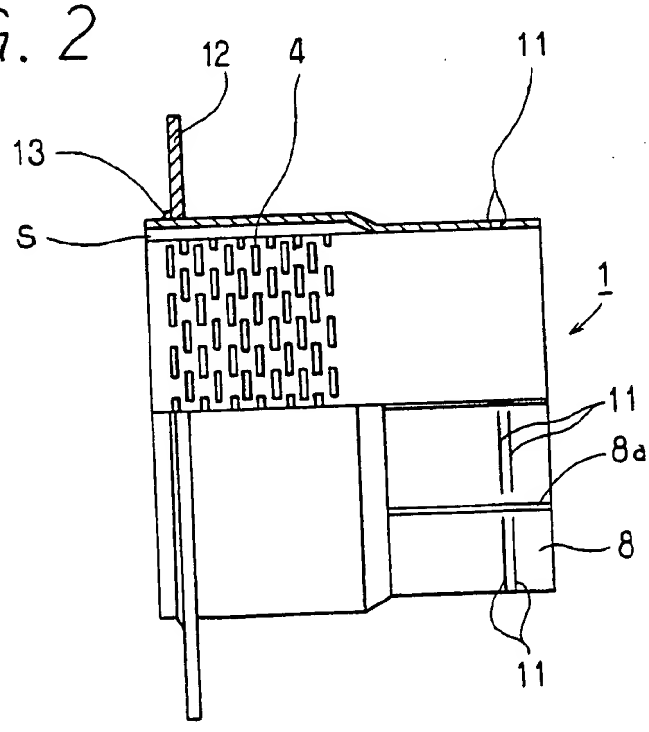
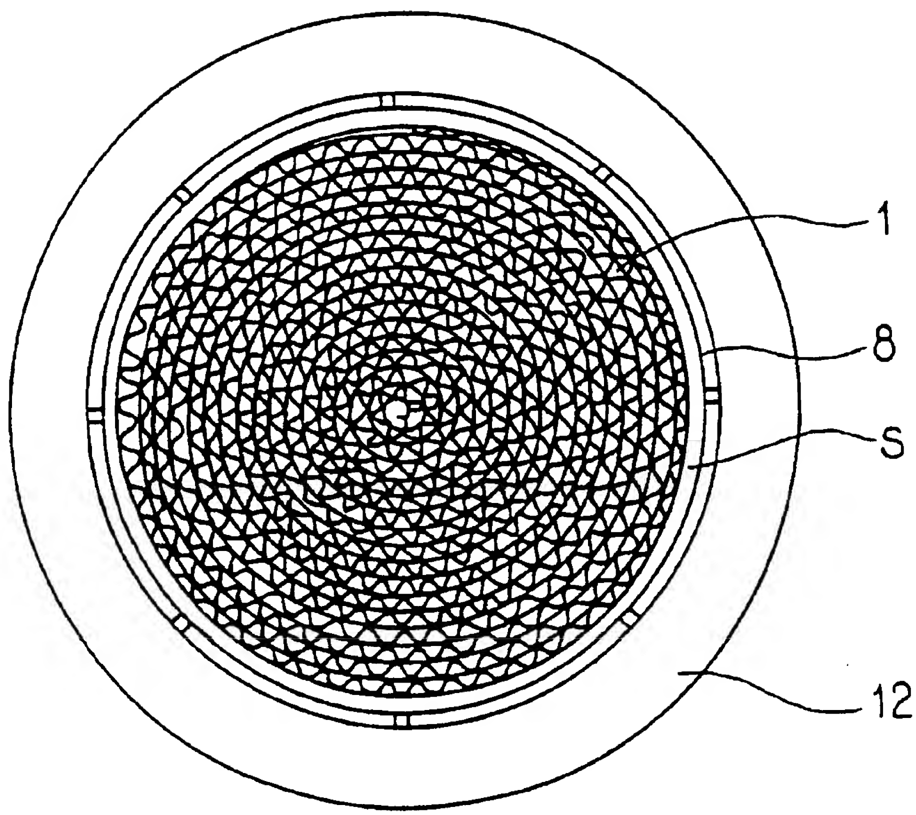


FIG. 3



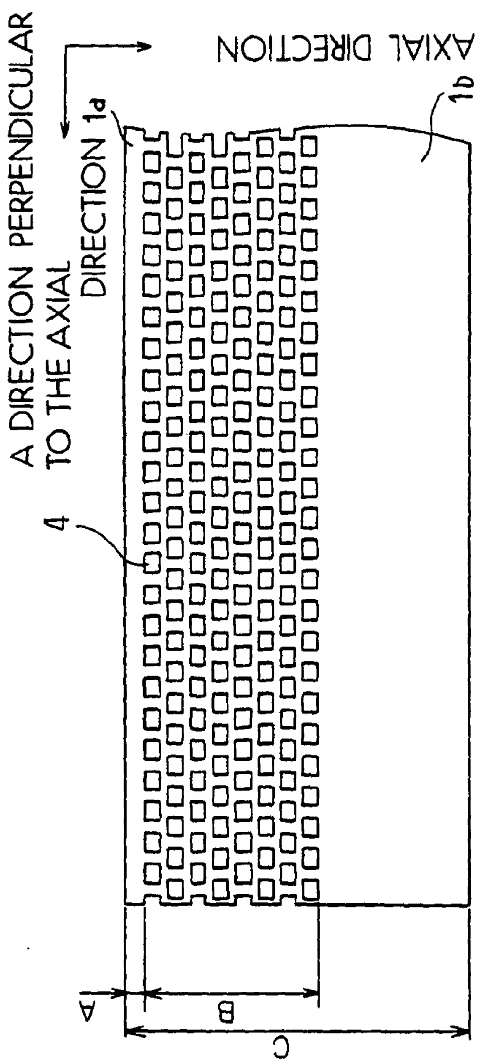

A DIRECTION PERPENDICULAR
TO THE AXIAL
DIRECTION
AXIAL DIRECTION
1a
1b
4
A
B
C

FIG. 4

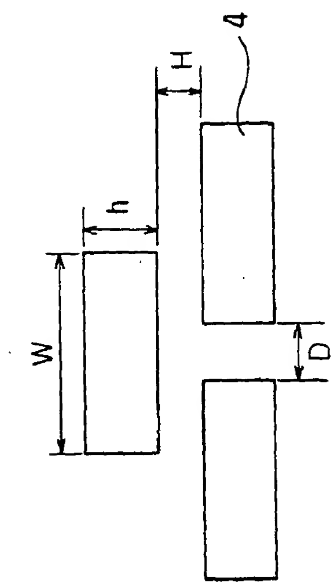
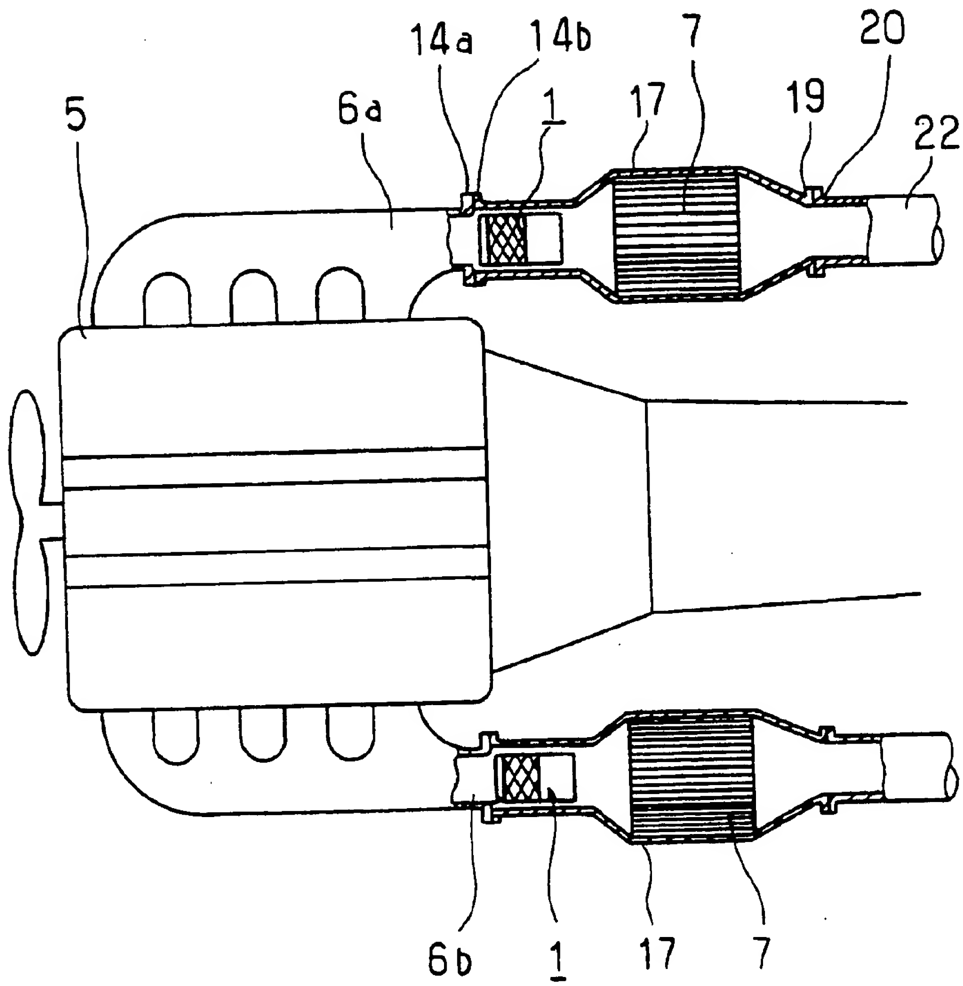

4
H
h
W
D

FIG. 5

FIG. 6



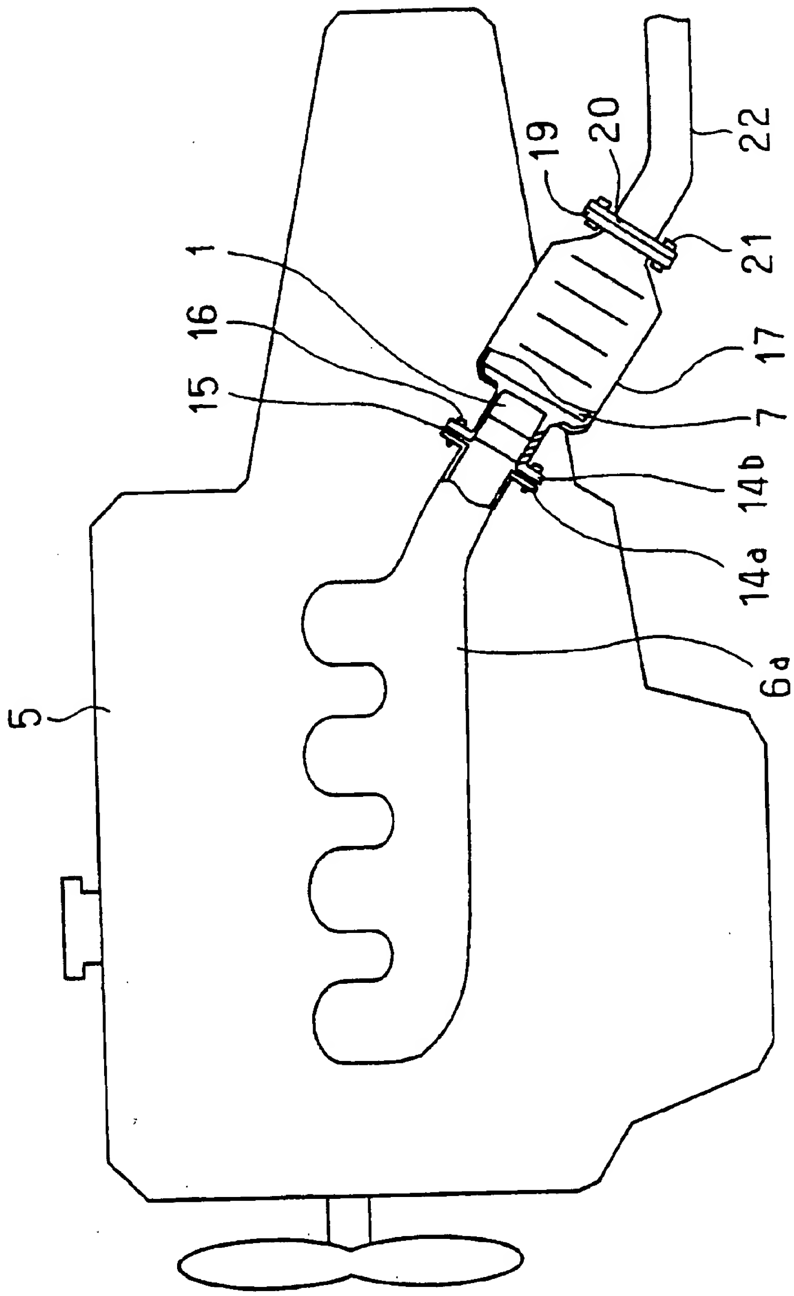


FIG. 7

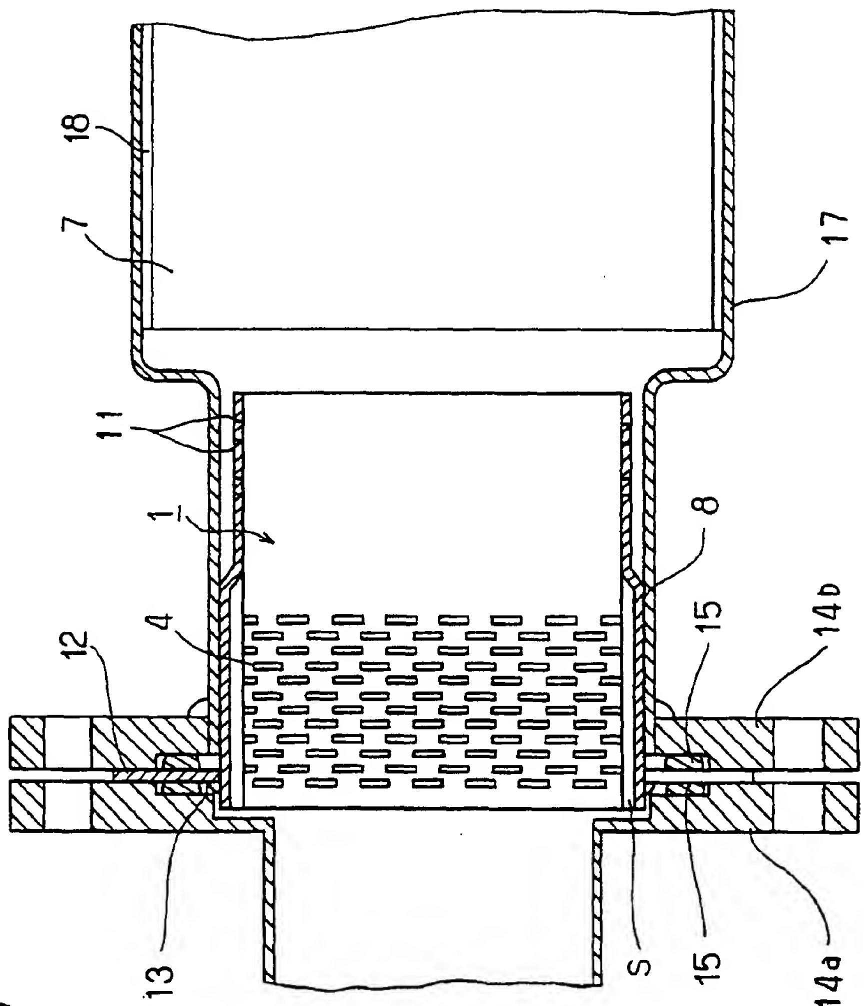


FIG. 8

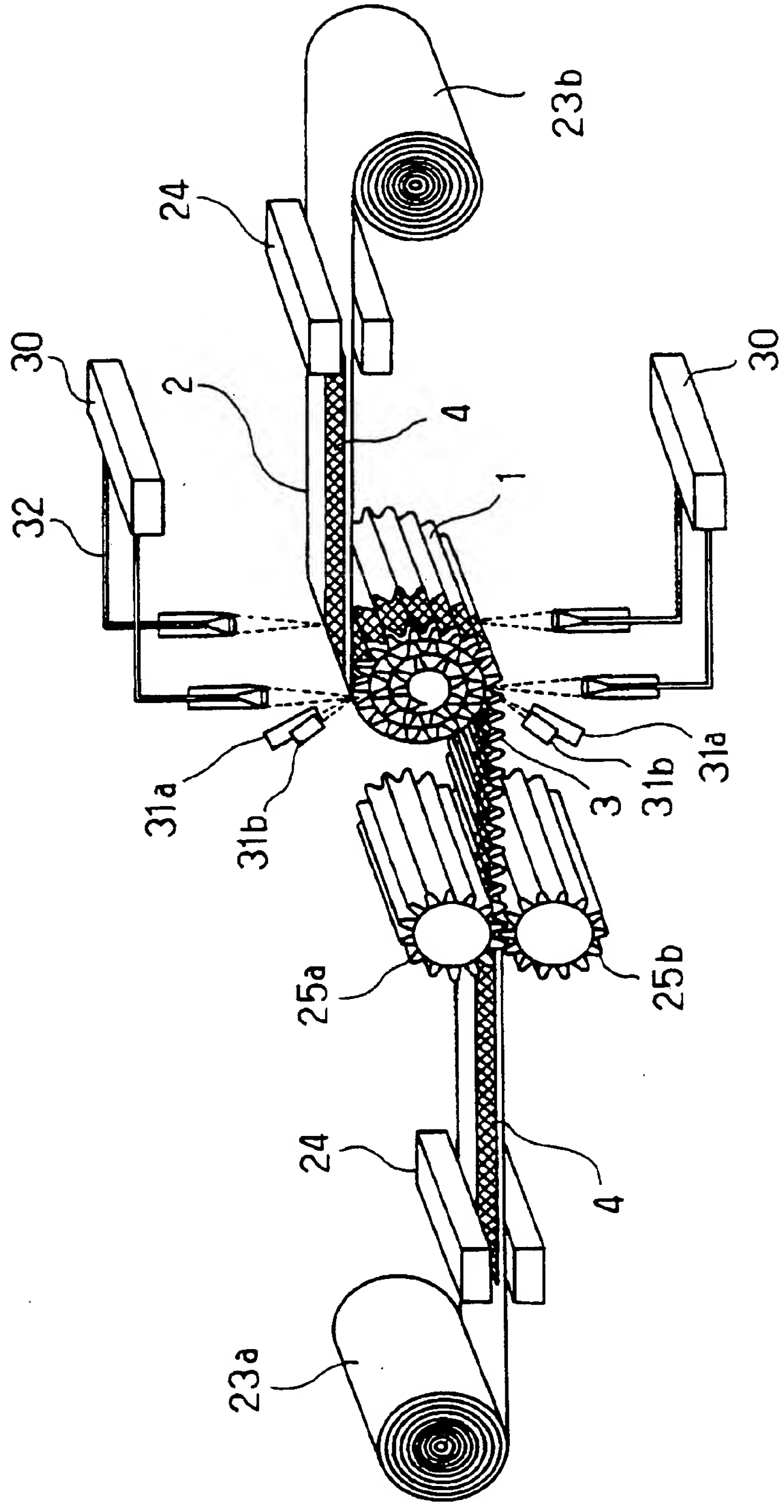


FIG. 9

FIG. 10

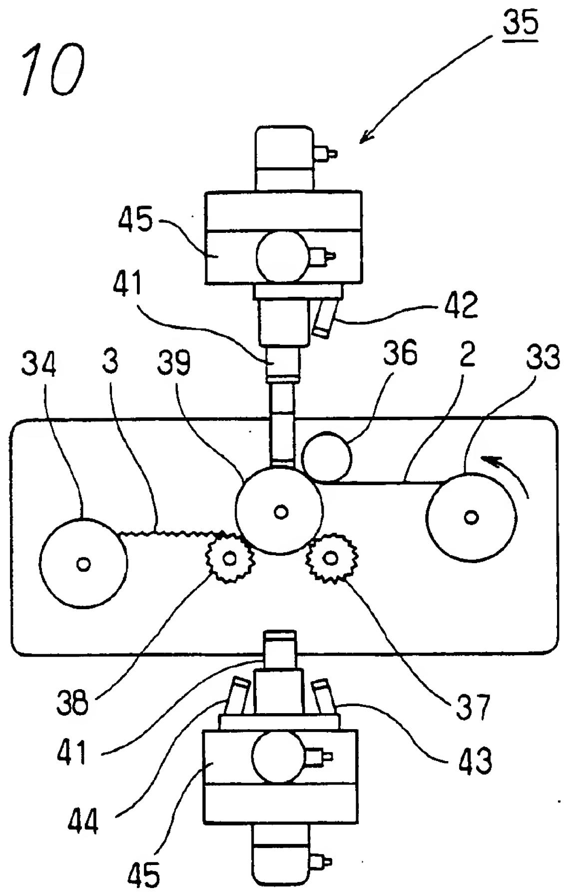


FIG. 11

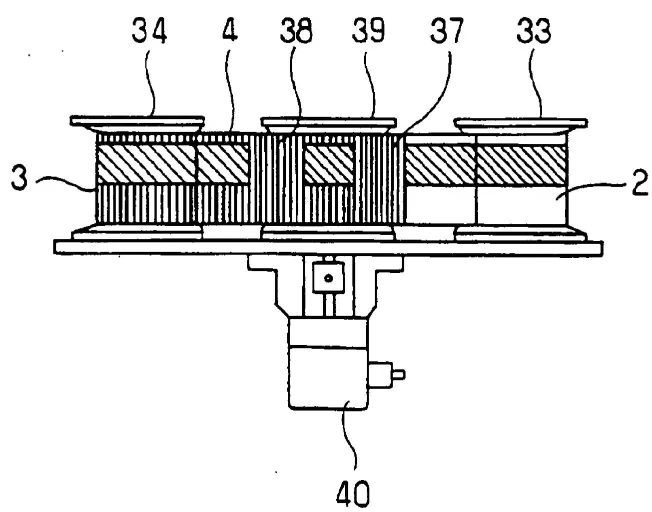


FIG. 12

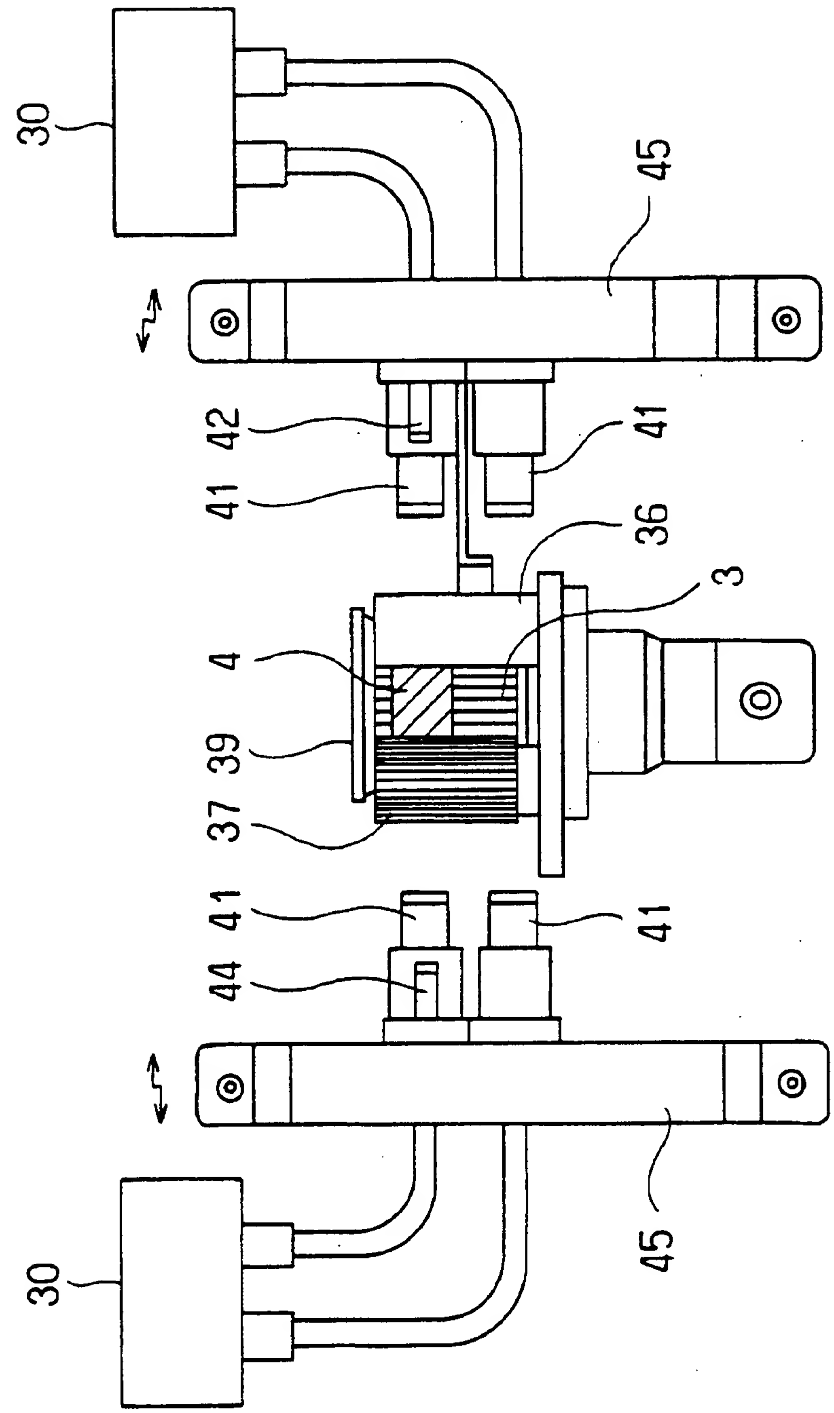


FIG. 13

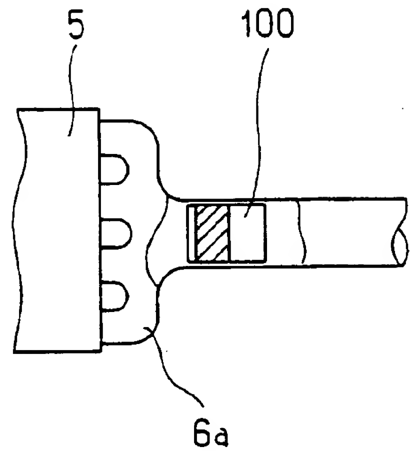


FIG. 14A

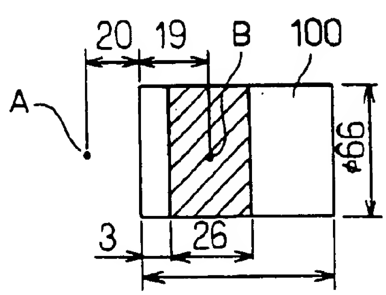


FIG. 14B

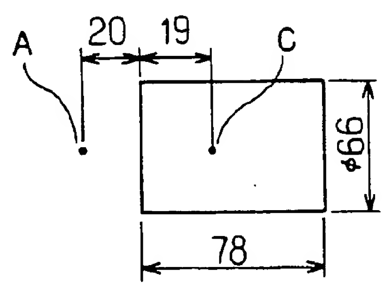


FIG. 15

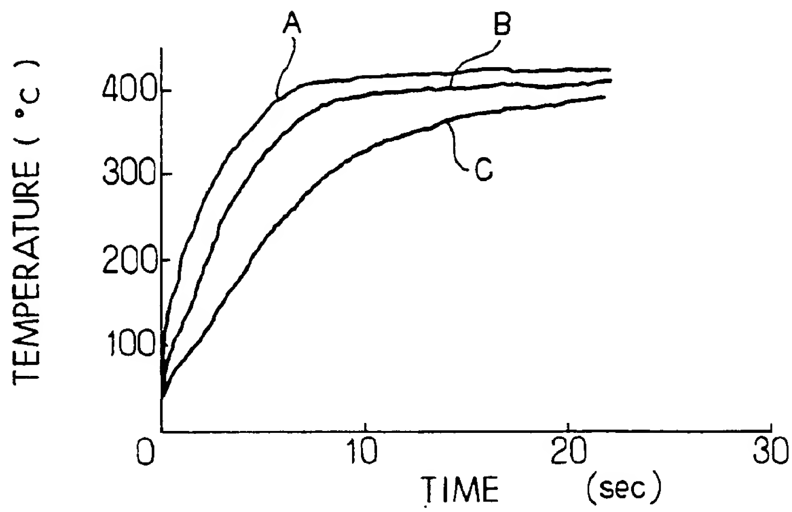

A
B
C
TEMPERATURE (°c)
400
300
200
100
0
10
20
30
TIME (sec)

FIG. 20

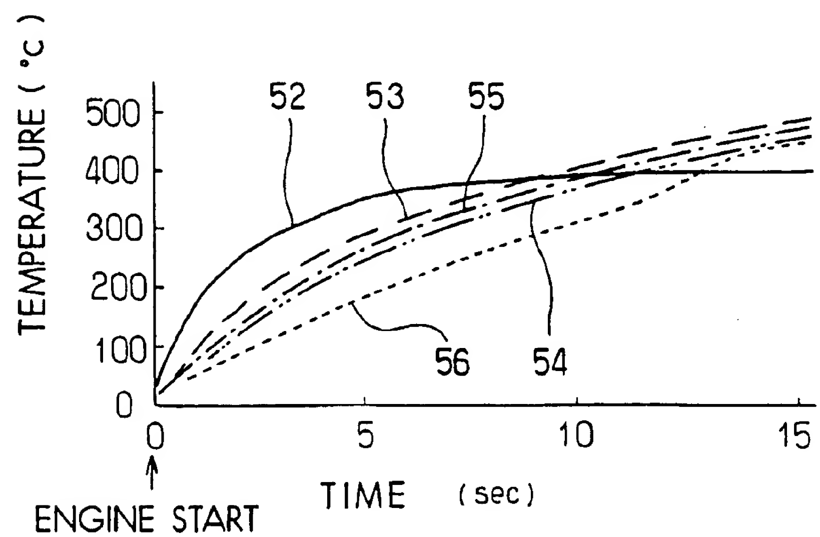

TEMPERATURE (°c)
500
400
300
200
100
0
52
53
55
56
54
0
5
10
15
ENGINE START
TIME (sec)

FIG. 16

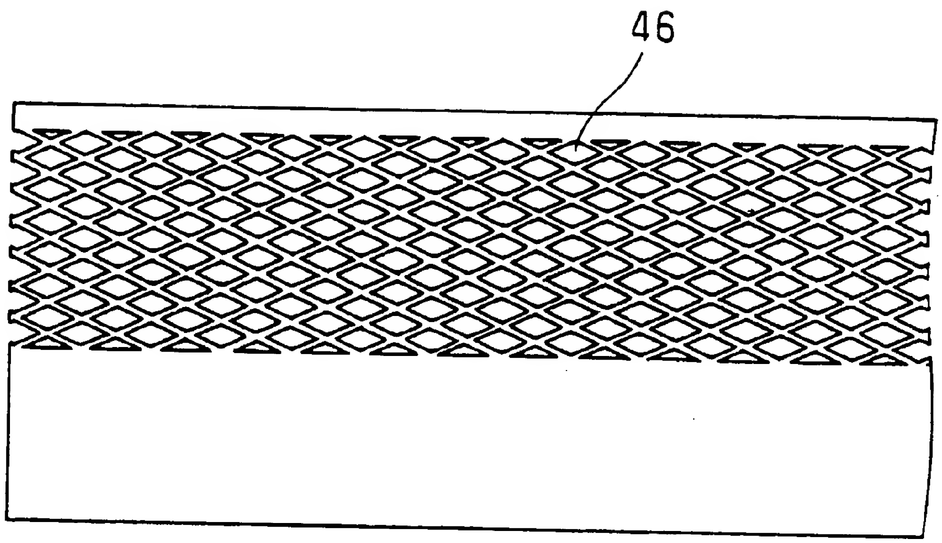


FIG. 17

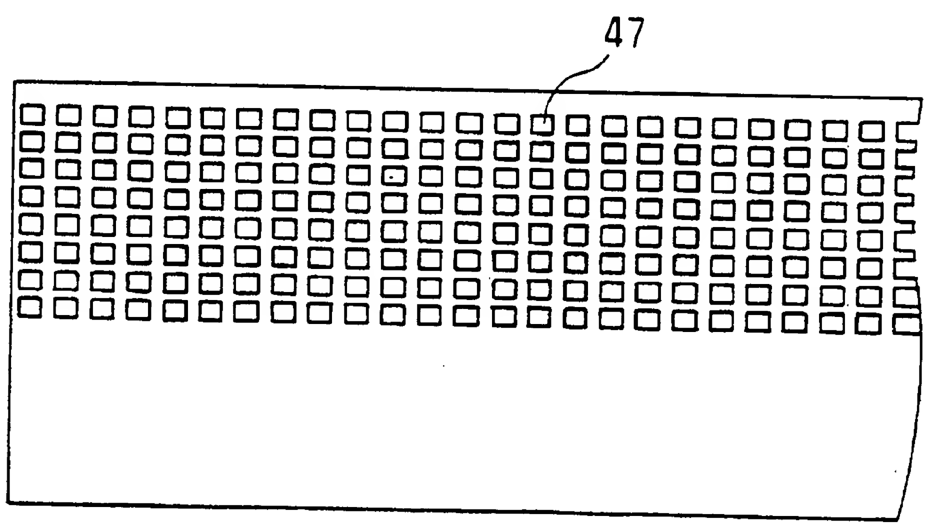


FIG. 18

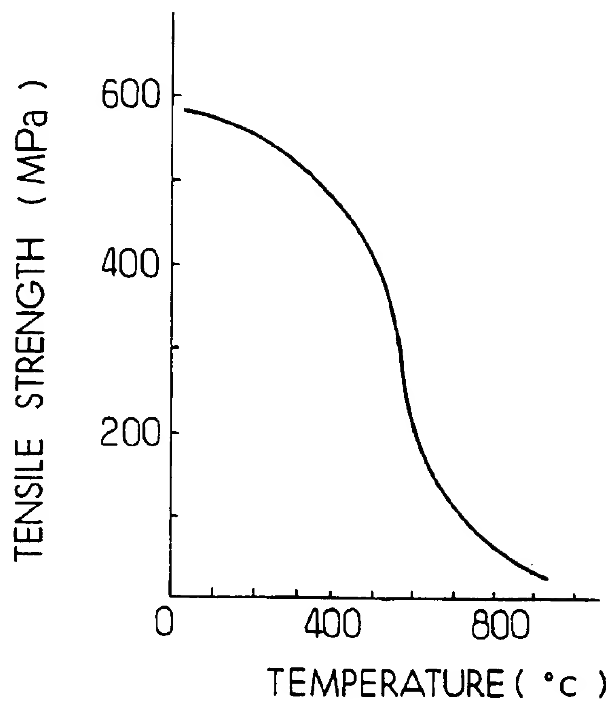

600
400
200
TENSILE STRENGTH (MPa)
0
400
800
TEMPERATURE (°c)

FIG. 19

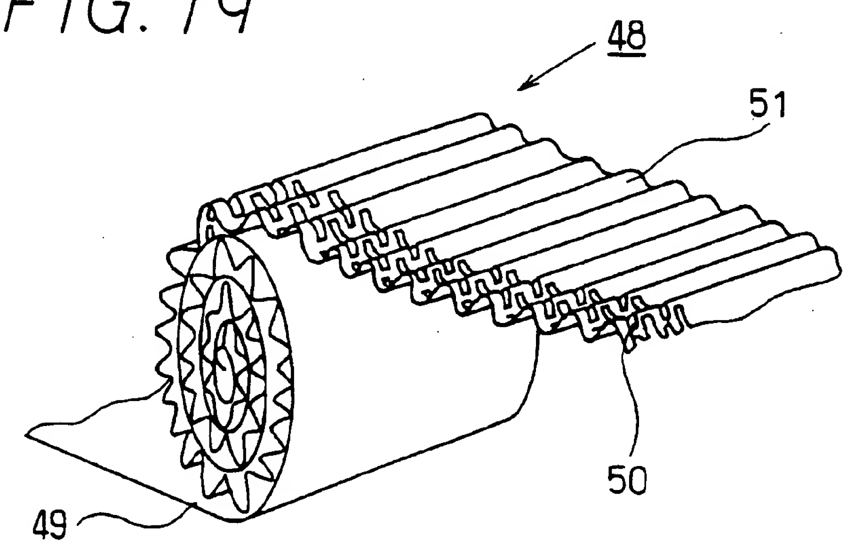

48
51
50
49

FIG. 21

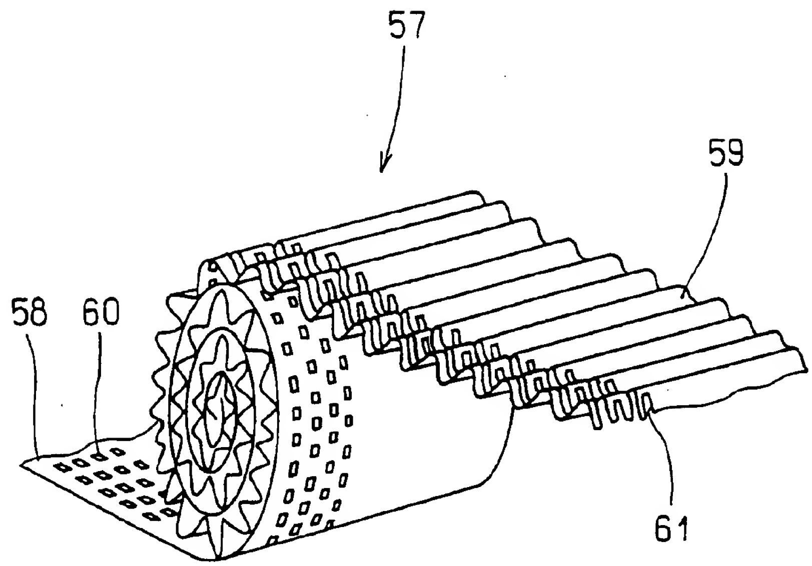


FIG. 22

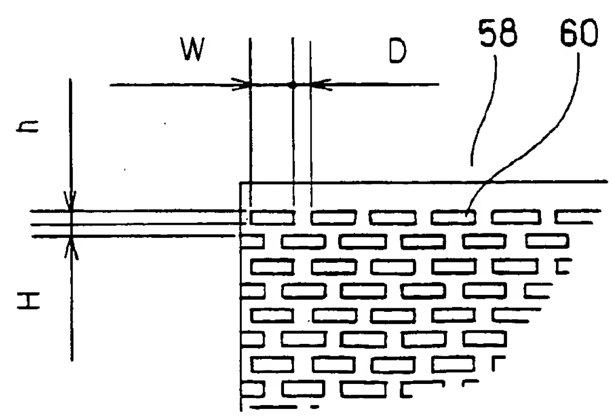


FIG. 23

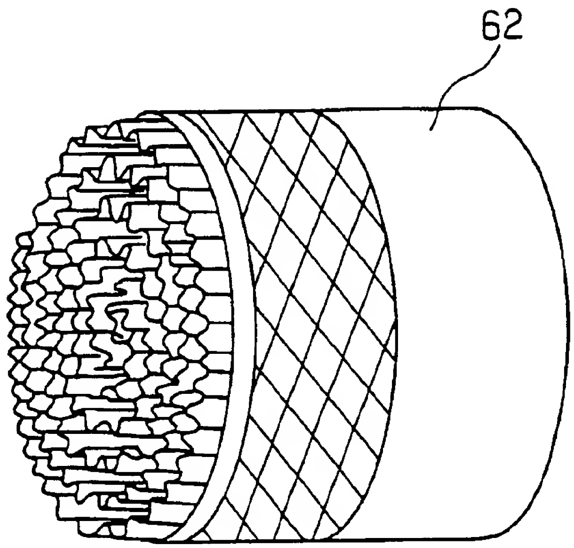


FIG. 24

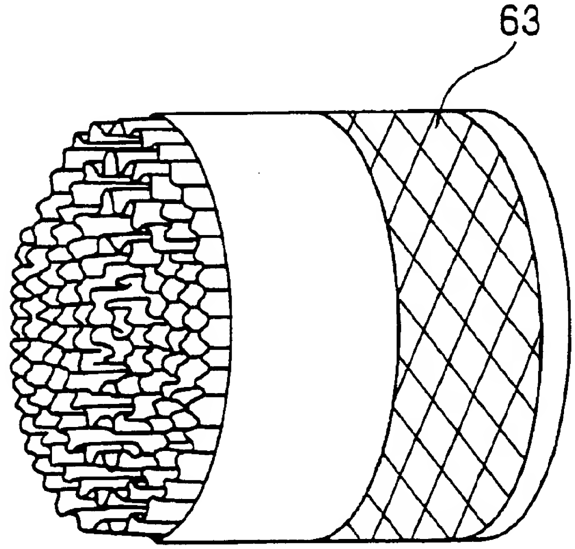


FIG. 25

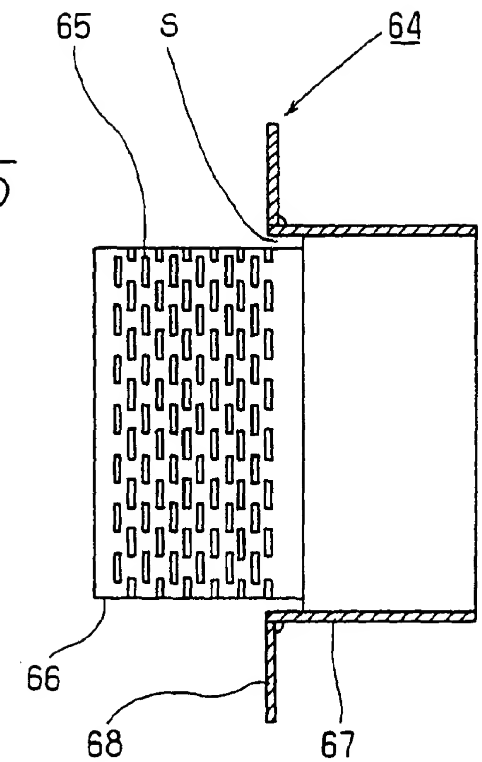
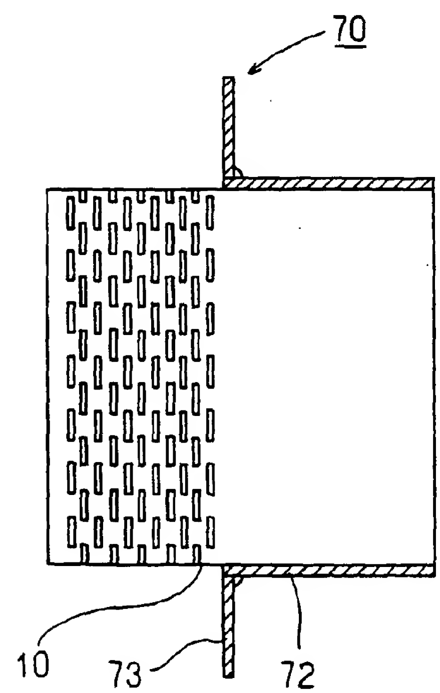


FIG. 27



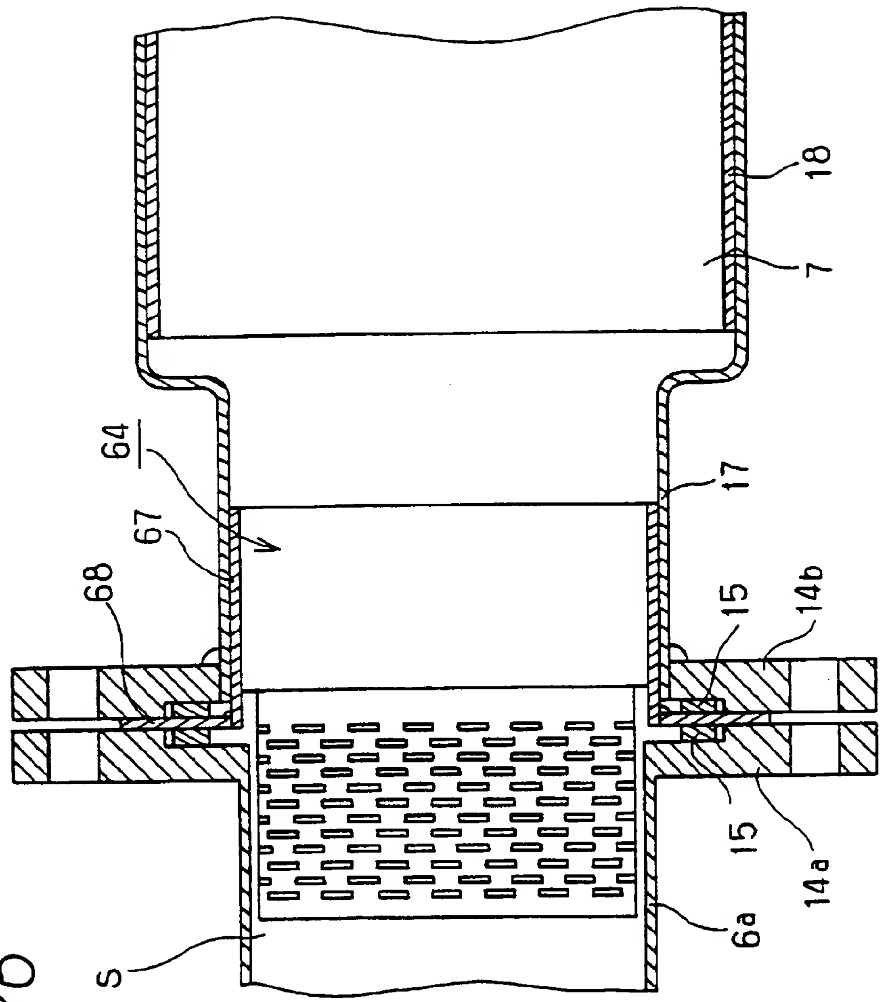


FIG. 26

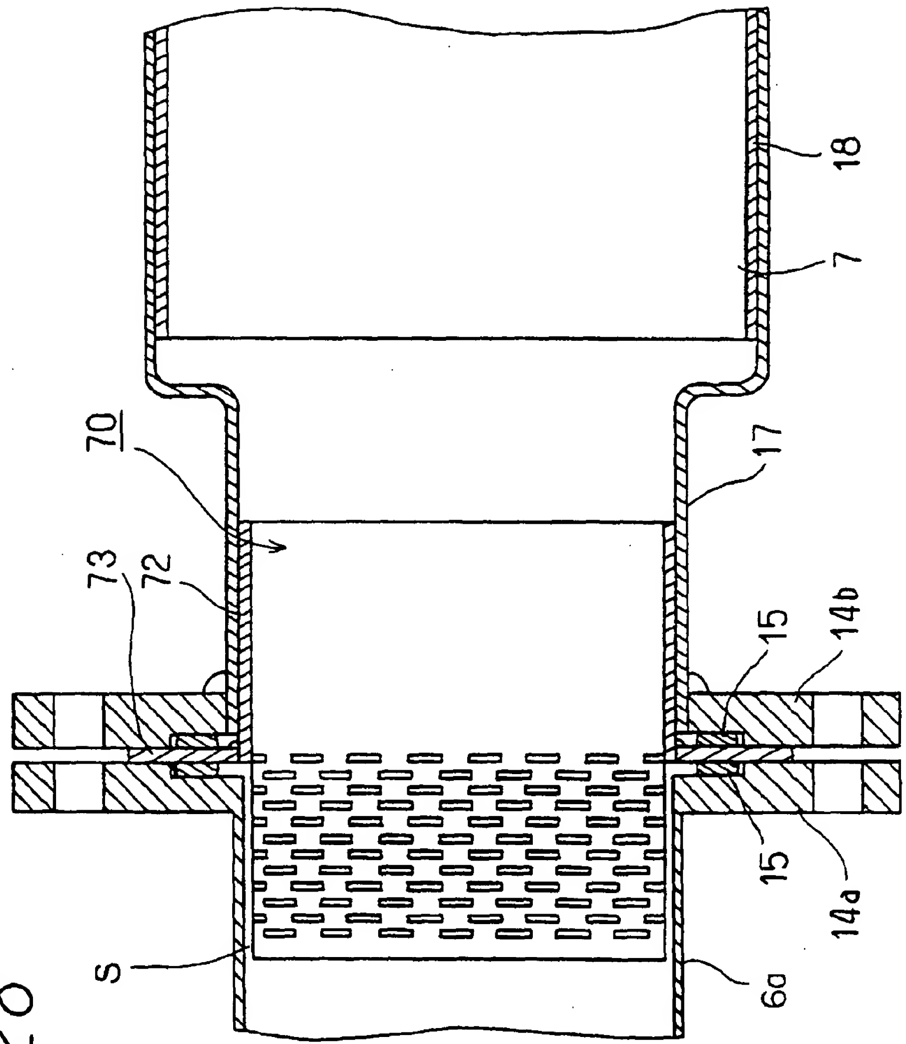


FIG. 28

FIG. 29

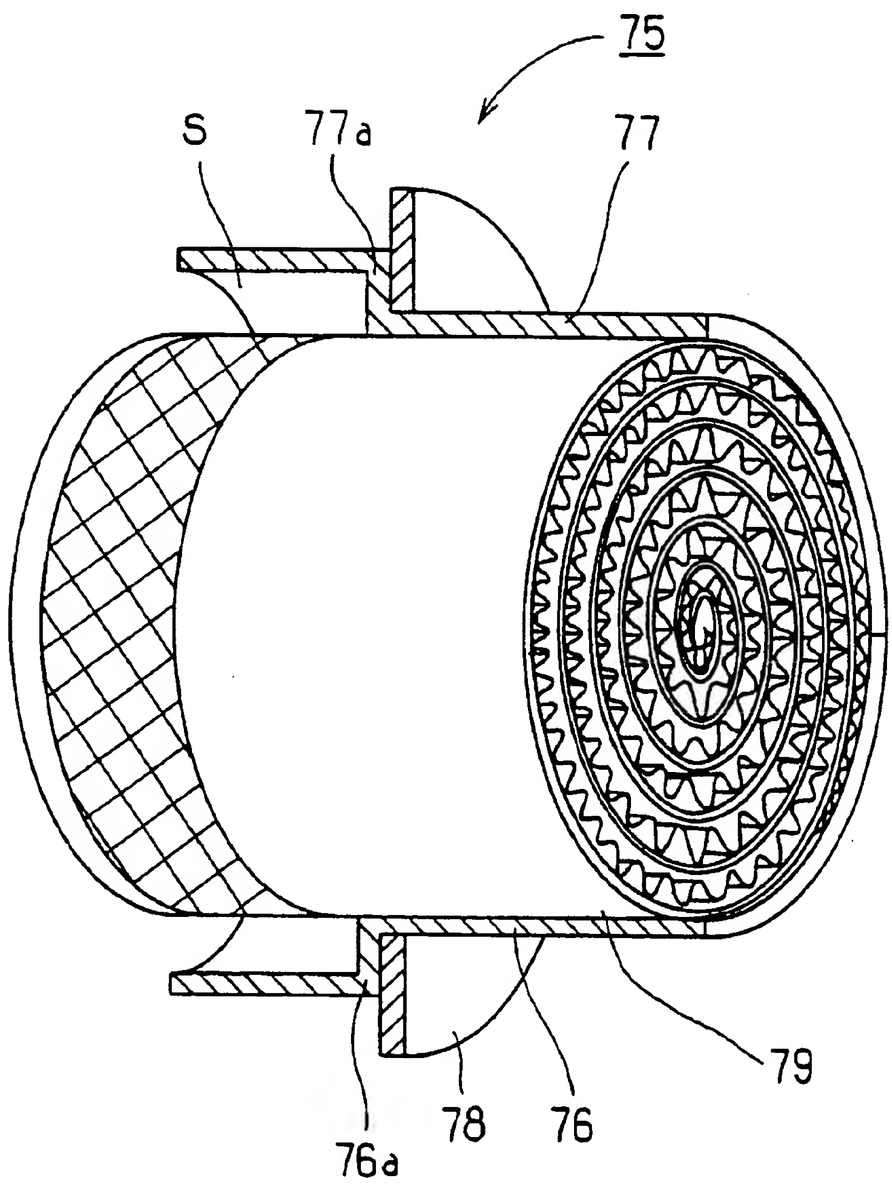


FIG. 30

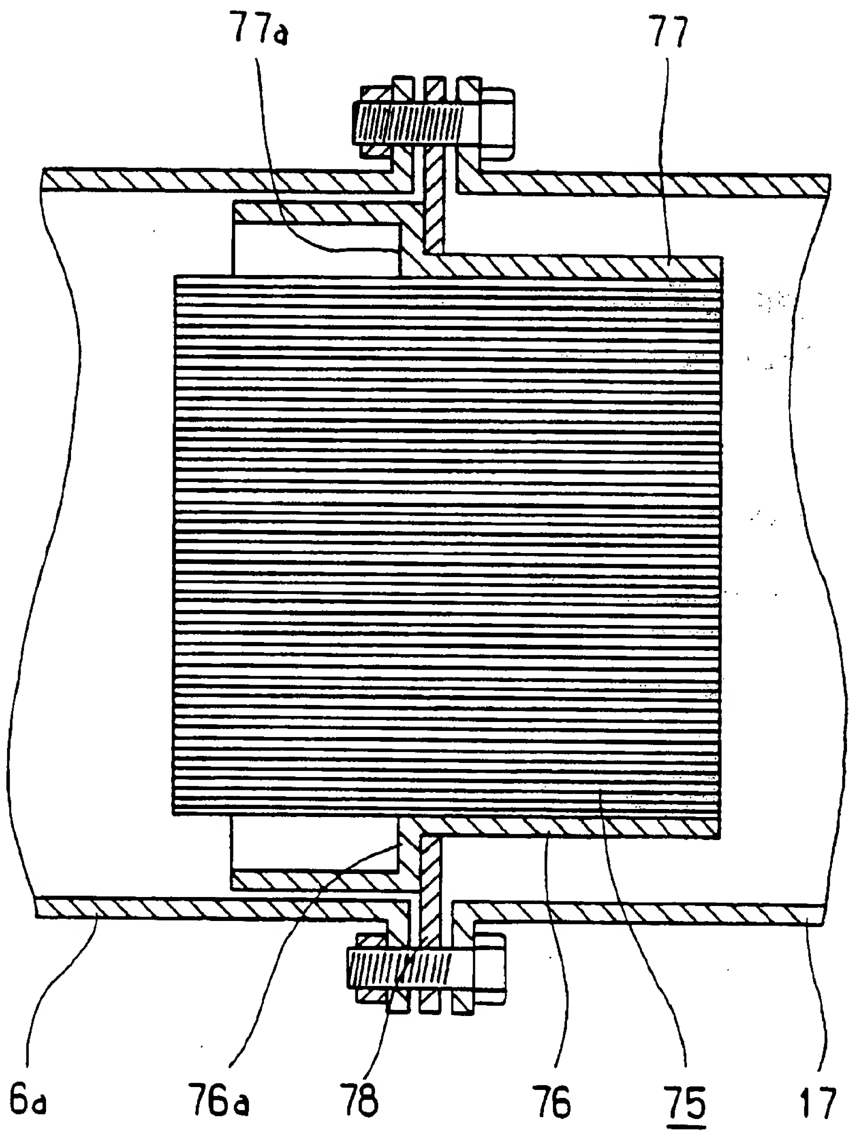


FIG. 31

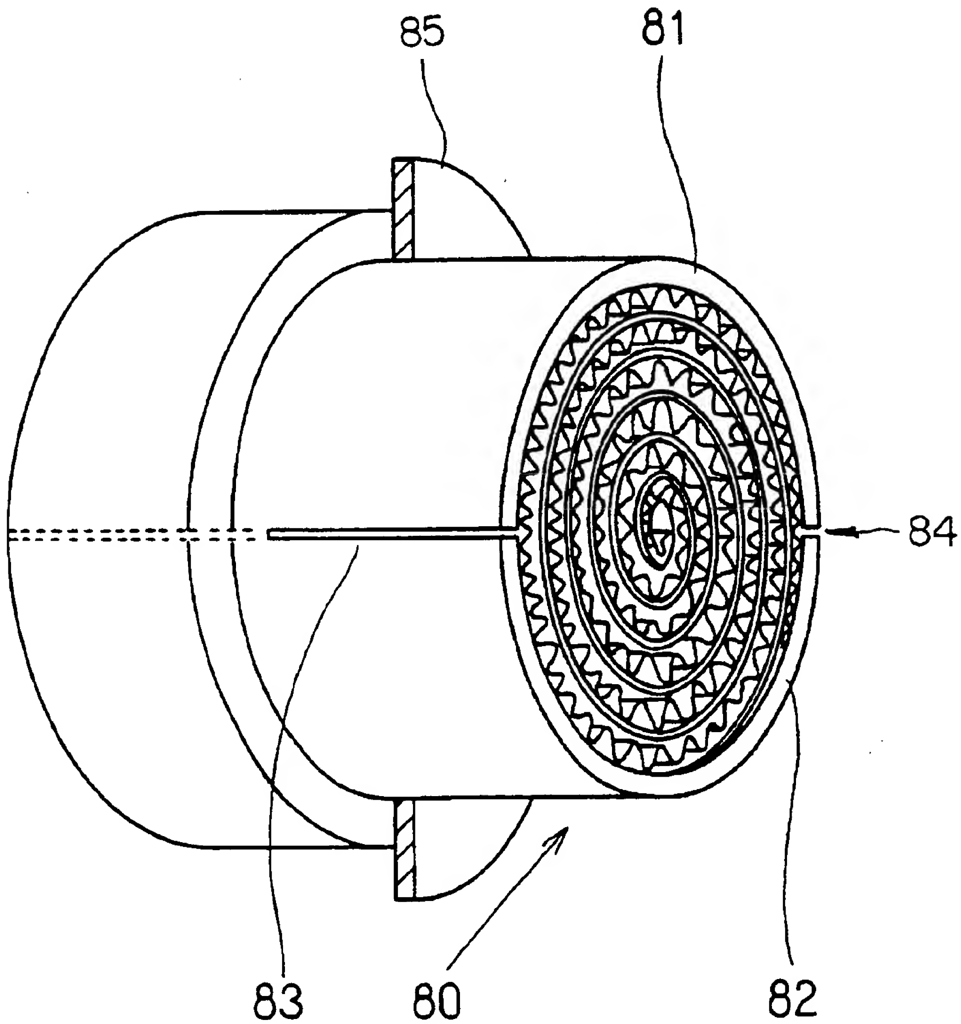


FIG. 32A

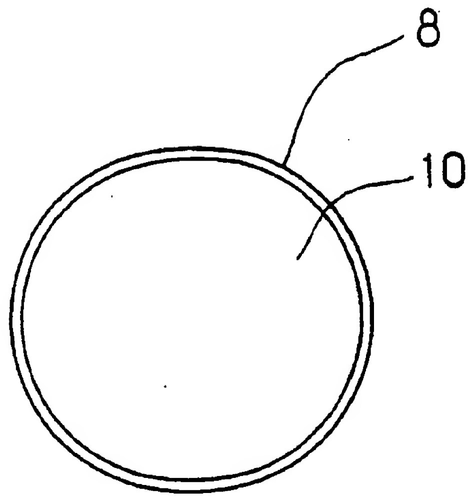


FIG. 32B

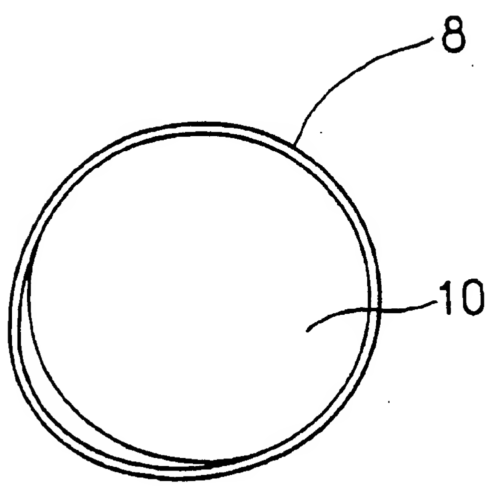


FIG. 33

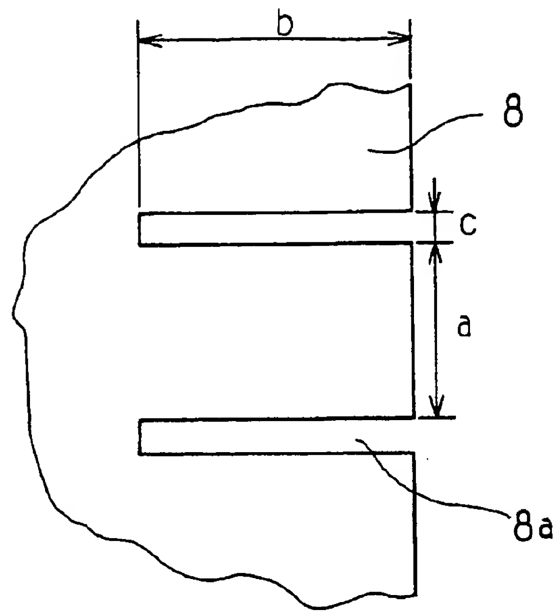


FIG. 34

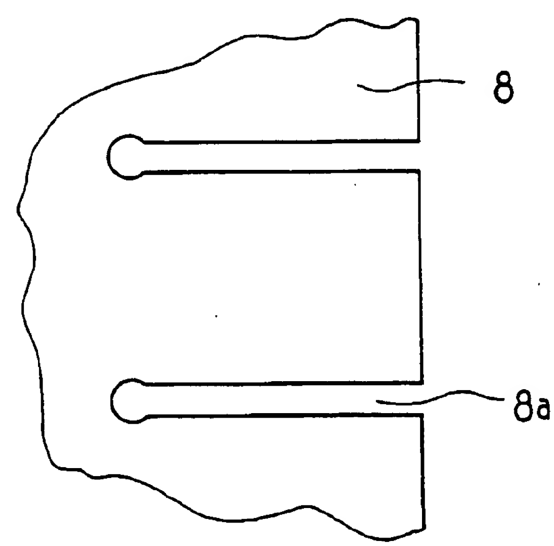


FIG. 35

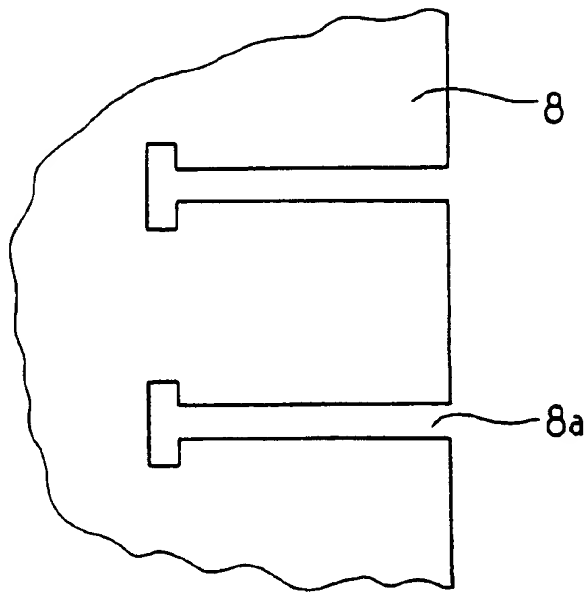


FIG. 36

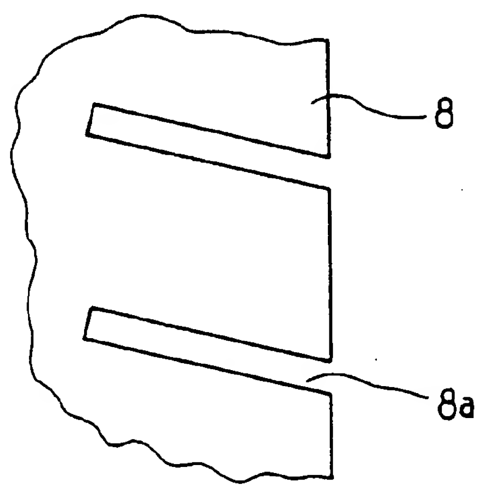


FIG. 37

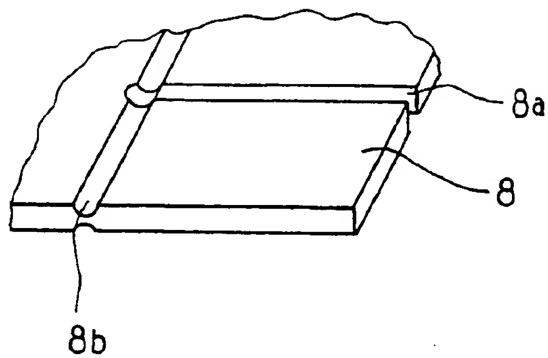


FIG. 38

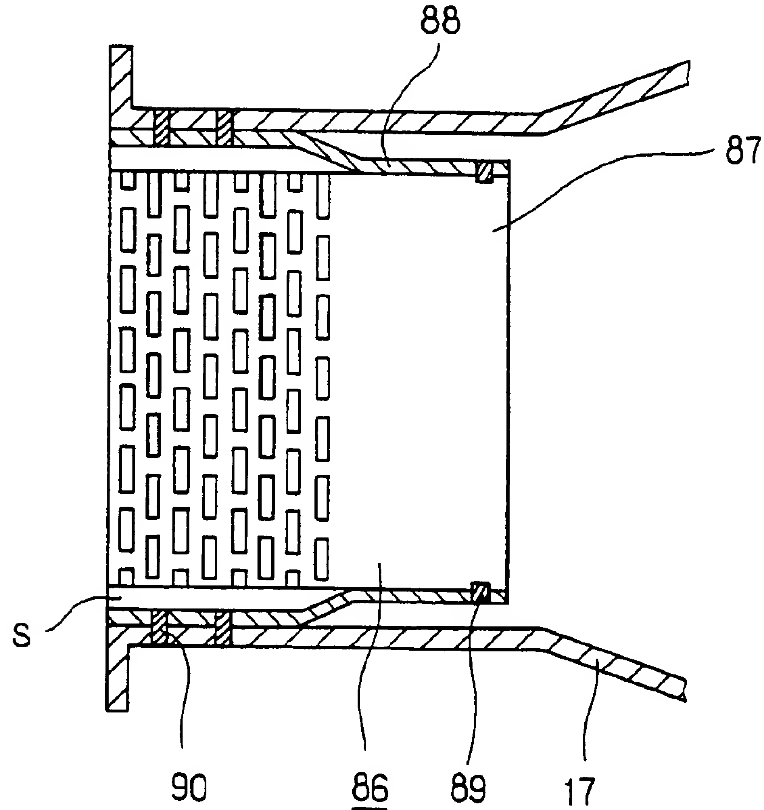
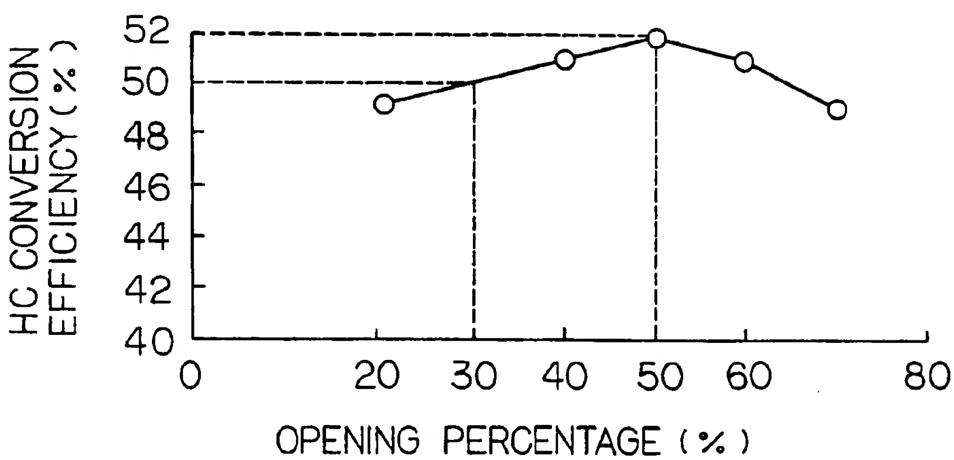


FIG. 39


HC CONVERSION EFFICIENCY (%)
52
50
48
46
44
42
40
0
20
30
40
50
60
80
OPENING PERCENTAGE (%)

HONEYCOMB BODY AND CATALYST CONVERTER HAVING CATALYST CARRIER CONFIGURED OF THIS HONEYCOMB

CROSS REFERENCE TO RELATED APPLICATION

This is a continuation-in-part application of U.S. application Ser. No. 213,806 filed Mar. 16, 1994, entitled METAL CARRIER by Toshiki Matsumoto et al.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention generally relates to a catalyst converter having honeycomb body of which temperature can rise at an early stage and a catalyst carrier which holds a catalyst capable of creating an oxidation-reduction reaction with the toxic elements in the exhaust gas, and of which temperature can rise at an early stage to the activation temperature where catalyst held in the catalyst carrier can perform catalyst functions to purify exhaust gas of automobiles, etc.

2. Description of the Related Art

Conventionally, as means to convert the toxic elements such as CO, and HOx found in the exhaust gas of automobile engines into harmless vapors (such as CO2) or water, a metal catalyst converter that was a catalyst converter comprising a metal catalyst carrier was intervened in the honeycomb placed inside the exhaust gas passage. With these means, the exhaust gas was purified.

Metal catalyst carriers formed by winding or laminating metal foil flat sheets or corrugated sheets are disclosed in the Japanese Utility Model Application Laid-Open No. 4-62316. However, with the metal catalyst carrier disclosed in Japanese Utility Model Application Laid-Open No. 4-62316 a problem existed. When the exhaust gas temperature at the initial engine running state was low, the catalyst properties were not activated, and the exhaust gas was not purified. This was caused because the heat capacity of the metal catalyst carrier itself was extremely large, it took a long time for the held catalyst to rise to the active temperature by just the heat transfer of the exhaust gas heat.

To resolve this problem, Japanese Utility Model Application Laid-Open No. 2-223622 proposed installing a catalyst converter comprising a self-heating type metal catalyst carrier besides the main catalyst converter to activate the catalyst properties by conducting and heating the self-heating metal catalyst carrier. However, a large power exceeding 1 kW is required for this type of catalyst converter, and thus the efficiency is extremely poor.

Furthermore, the metal catalyst carrier for automobiles is installed in the engine exhaust gas passage and is direct subjected to exhaust gases that exceed 900° C. Thus, a repeated function of thermal expansion and contraction is applied. Thus, a metal catalyst carrier provided with slits on the entire metal foil flat sheet and corrugated sheet to absorb the thermal expansion and contraction was disclosed in Japanese Utility Model Application Laid-Open No. 3-71177.

However, with the metal catalyst carrier disclosed in Japanese Utility Model Application Laid-Open No. 3-71177, as fine long slits are formed throughout the flat sheet and corrugated sheet to extend in the direction that crosses with the exhaust gas direction, not only does the rigidity of the metal catalyst carrier itself drop, but also the characteristic frequency drops making it extremely difficult to secure the

reliability in regard to the engine vibration. Furthermore, the metal catalyst carrier may break when the strength of the metal drops remarkably at high temperatures exceeding 900° C.

Furthermore, as slits are arranged throughout the metal foil flat sheet and corrugated sheet that configure the metal catalyst carrier, it is extremely difficult to join the flat sheet and corrugated sheet, making complicated manufacturing device, and causing difficulties in inexpensive manufacturing.

SUMMARY OF THE INVENTION

An object of this invention is to provide carrier structure having a high heat transfer efficiency to efficiently transfer the exhaust gas heat to the entire honeycomb, an easy-to-manufacture honeycomb body with a very small heat capacity and high reliability, and a catalyst converter configured of this honeycomb body.

Another object of this invention is to provide an inexpensive honeycomb body and catalyst carrier having a high reliability that can raise the temperature of the held catalyst to the activation temperature without using electrical means in a short time after the engine is started.

To achieve the objects of this invention, a honeycomb body arranged in the exhaust gas passage of an engine, has a low heat capacity area formed at the upstream side of the exhaust gas passage. The area is smaller in capacity than the downstream side of the exhaust gas passage. A catalyst converter uses this honeycomb body.

It is preferable that the honeycomb body be configured by alternately winding or laminating metal flat sheets and/or corrugated sheets, and a slit matrix having openings created by a plurality of slits that extend perpendicular to the direction of the exhaust gas which flows through said exhaust gas passage is formed at the upstream side of the flat sheet and/or corrugated sheet exhaust gas passage.

It is also preferable that the aspect ratio h:W of each slit be 1:5 or less.

A catalyst converter has a catalyst carrier arranged in exhaust gas passage or engine wherein the catalyst that causes an oxidation-reduction reaction with toxic elements in exhaust gas emitted from the engine is held, and wherein low heat capacity area is formed only at the upstream side of the exhaust gas passage, the area is smaller in heat capacity than the downstream side of the exhaust passage, and wherein outer casing having an air insulation layer space at the area corresponding to the low heat capacity area of the catalyst carrier is formed.

It is also preferable that the catalyst converter have a plurality of openings formed in a slit matrix on the outer casing with intervals in the circumference direction on at least part of the portion that joins with the catalyst carrier, wherein the openings can thermally deform in the direction that the catalyst carrier radially expands and contracts.

It is also preferable that the catalyst carrier be formed by winding or laminating flat sheets and/or corrugated sheets, and that the flat sheet and/or corrugated sheet joining section by joined at the non-slit matrix portion near the upstream and downstream sides of the slit matrix that creates the low heat capacity area, and at the axial cross section of the catalyst converter including the air insulation layer portion that does not contact the outer casing.

This invention relates to the metal catalyst carrier comprising the above configuration and characteristics.

According to the present invention with the configuration, as a low heat capacity area, of which heat capacity is smaller than downstream side of exhaust gas passage, is formed on the upstream side of the exhaust gas passage in the honeycomb, the temperature of the honeycomb body can be easily raised by the exhaust gas from the engine.

By forming this low heat capacity area, the heat transfer efficiency for the entire honeycomb is high, and the radius direction and axial direction heat transfer amount of the honeycomb body can be small. Thus, a honeycomb body with an outstanding effect for keeping the heat of which temperature has been raised is achieved.

By forming an air insulation area in the area corresponding to the low heat capacity area and creating an insulated structure, discharge of the heat of which temperature was raised in the low heat capacity area to the outside along the outer casing can be prevented.

Thus, a structure that easily raises the temperature of the catalyst carrier by the exhaust gas heat only is achieved and the temperature rasing efficiency can be improved with an extremely small amount of the heat being discharged to the outer casing.

As explained above, when the temperature of the low heat capacity area at the upstream side is raised, the transfer of heat to the downstream side of the exhaust gas passage on the honeycomb body starts. The heat capacity of the downstream side of the exhaust gas passage is larger than the upstream side exhaust gas passage, so the heat transfer is high, and the heat of which temperature is raised at the upstream side of the exhaust gas passage is quickly transferred to the down stream side of the exhaust gas passage allowing the entire honeycomb to be easily heated.

A slit matrix having openings formed by a plurality of slits extending in the direction perpendicular to the direction of the exhaust gas is formed in this low heat capacity area. When the-temperature of the slit matrix on the upstream side of this exhaust gas passage rises, the transfer of the heat to the downstream side of the exhaust gas passage on the honeycomb starts. As there is non-slit matrix portion on the downstream side of this exhaust gas passage, the heat transfer is high, and as the catalyst reaction heat is also applied, the heat of which temperature was raised at the upstream side is quickly transferred to the downstream side, and the temperature of the honeycomb can be raised easily. On the other hand, the structure ensures that the honeycomb strength is sufficient.

In other words, as slits having a small aspect ratio are formed for the slits that configure the slit matrix, the honeycomb body can be configured without dropping the characteristic frequency in the axial and radial directions. Thus, the durability is outstanding.

Furthermore, as the heat capacity of the upstream side of the exhaust gas passage in the catalyst carrier is smaller than the heat capacity of the downstream side of the exhaust gas passage, when the temperature of the low heat capacity area on the upstream side of the exhaust gas passage rises, the transfer of the heat to the downstream side of the catalyst carrier starts. Since the heat capacity of the downstream side is larger than the upstream side of the exhaust gas passage, the heat transfer is high and as the catalyst reaction heat is also applied, the heat amount of which temperature is raised at the upstream side is swiftly transferred to the downstream side. As a result, the entire catalyst carrier area easily reaches the catalyst activation temperature.

This allows an exhaust gas reaction area that can sufficiently purify the exhaust gas immediately after the engine is started to be achieved in a short time. As multiple openings are formed with intervals in the circumferential direction on the outer casing at the downstream side that contacts the metal catalyst carrier, the openings can thermally deform in the radial thermal expansion and contraction direction of the metal catalyst carrier, and the radial direction thermal strain that occurs on the joining section of the outer casing and metal catalyst carrier is also small.

As the flat sheets and corrugated sheets that configure the metal catalyst carrier are joined at the nonslit matrix portion, the peak of the corrugated sheet can be easily and inexpensively joined to the flat sheet with laser welding, resistance welding or brazing, etc. The flat sheets and corrugated sheets that configure the metal catalyst carrier area joined at the upstream and downstream sides that sandwich the slit matrix that does not contact the outer casing. As the outer casing and welded sections do not directly contact, the thermal gradient in the radius direction of the catalyst carrier is extremely small. Thus, the thermal strain of the metal catalyst carrier that occurs in the cooling/heating cycle by the engine up/down can be reduced. Furthermore, as the outer casing is joined with the metal catalyst carrier only near the downstream end, the axial direction thermal stress that occurs at this joining section is extremely small.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a partially cutaway view illustrating the metal catalyst converter according to the first embodiment;

FIG. **2** is a front view illustrating the metal catalyst converter according to the first embodiment;

FIG. **3** is a right view illustrating the metal catalyst converter according to the first embodiment;

FIG. **4** is a development view illustrating the flat sheets and corrugated sheets used in the metal catalyst converter according to the first embodiment;

FIG. **5** is a partially enlarged view of the slit portion used in the first embodiment;

FIG. **6** is an outline configuration view of the engine in which the metal catalyst converter according to the first embodiment is mounted;

FIG. **7** is a front view of the engine in which the metal catalyst converter according to the first embodiment is mounted;

FIG. **8** is a partial cross-sectional view illustrating the structure for holding the metal catalyst converter according to the first embodiment;

FIG. **9** is a simulation view of the manufacturing device for manufacturing the metal catalyst carrier according to the first embodiment;

FIG. **10** is a front view of the manufacturing device for manufacturing the metal catalyst carrier according to the first embodiment;

FIG. **11** is a top view of the manufacturing device for manufacturing the metal catalyst carrier according to the first embodiment;

FIG. **12** is a right view of the manufacturing device for manufacturing the metal catalyst carrier according to the first embodiment;

FIG. **13** is an explanatory view illustrating the position of the metal catalyst converter and engine in the comparative experiment;

FIG. **14**A is a side view of the metal catalyst carrier for the comparative experiment;

FIG. **14B** is a side view of the metal catalyst carrier for comparison purposes in the comparative experiment;

FIG. **15** is a characteristic diagram illustrating the results of the comparative experiment;

FIG. **16** is a development view illustrating other embodiments of the slits used in the present invention;

FIG. **17** is a development view illustrating other embodiments of the slits used in the present invention;

FIG. **18** is a characteristic diagram illustrating the relation between the material temperature and tensile strength;

FIG. **19** is a development view illustrating the metal catalyst carrier according to the second embodiment;

FIG. **20** is a characteristic diagram illustrating the relation between the time and temperature in the second embodiment and comparison embodiment;

FIG. **21** is a simulation view illustrating the metal catalyst carrier according to the third embodiment during rotation;

FIG. **22** is a partial enlargement view of the slits used for the third embodiment;

FIG. **23** is a simulation view illustrating the metal catalyst carrier according to the fourth embodiment;

FIG. **24** is a simulation view illustrating the metal catalyst carrier according to the fourth embodiment;

FIG. **25** is a simulation view illustrating the metal catalyst converter according to the fifth embodiment;

FIG. **26** is a partial cross-sectional view illustrating the structure for holding the metal catalyst converter according to the fifth embodiment;

FIG. **27** is a simulation view illustrating the metal catalyst converter according to the sixth embodiment;

FIG. **28** is a partial cross-sectional view illustrating the structure for holding the metal catalyst converter according to the sixth embodiment;

FIG. **29** is a simulation view illustrating the metal catalyst converter according to the seventh embodiment;

FIG. **30** is a partial cross-sectional view illustrating the structure for holding the metal catalyst converter according to the seventh embodiment;

FIG. **31** is a simulation view illustrating the metal catalyst converter according to the eighth embodiment;

FIG. **32**A and FIG. **32**B are explanatory views illustrating the problems in the eighth embodiment;

FIG. **33** is a development view of the slits used in the ninth embodiment;

FIG. **34** is a development view of the slits used in the ninth embodiment;

FIG. **35** is a development view of the slits used in the ninth embodiment;

FIG. **36** is a development view of the slits used in the ninth embodiment;

FIG. **37** is a development view of the slits used in the ninth embodiment;

FIG. **38** is a partial cross-sectional view of the metal catalyst converter according to the nine embodiment; and

FIG. **39** is a characteristic diagram illustrating the relation between opening percentage and HC conversion efficiency.

DETAILED DESCRIPTION OF THE PRESENTLY PREFERRED EXEMPLARY EMBODIMENTS

(First Embodiment)

The first embodiment according to the present invention will be described in reference to FIGS. **1** to **8**.

The metal catalyst carrier **10** in the first embodiment is configured of alternately layering flat sheet **2** and corrugated sheet **3** of heat resistant stainless steel and winding them in a spiral shape. Both the flat sheet **2** and corrugated sheet **3** are band-shaped heat resistant stainless steel foil having a width of 60 mm and thickness of 0.03 to 0.20 mm, and composed of Fe—Cr—Al composition, in detail, composed of chrome (Cr, 18 to 24 wt %), aluminum (Al, 4.5 to 5.5 wt %), rare earth metal elements (REM, 0.1 to 0.2 wt %) and remaining iron (Fe).

As illustrated in FIG. **4**, slit matrix having a plurality of slits **4** are formed on the flat sheet **2** and corrugated sheet **3**. The slits **4** have an approximate rectangular shape. The slit matrix starts from distance A (3 mm in this embodiment) from the one end of the sheet by a slit matrix width B (31.2 mm in this embodiment) to extend to the other end of the sheet. As illustrated in FIG. **5** the dimensions of the slit matrix are 3 mm in width W and 1.2 mm in height h. The slits are formed continuously in staggered pattern.

Furthermore, adjacent slits are formed with an interval H=0.8 mm in the axial direction of the metal catalyst carrier **10**, and an interval of adjacent slits arranged in the direction perpendicular to the axial direction D=1 mm in perpendicular to the axial direction of the metal catalyst carrier **10**. Furthermore, adjacent slits arranged in the axial direction are offset by a distance of (W+D)/2 to a direction perpendicular to the axial direction of the metal catalyst carrier **10**. The low heat capacity area is formed by the formation of this slit matrix.

The flat sheet **2** and the corrugated sheet **3** with a pitch of 4.9 mm and height of 1.7 mm are, after winding, installed so that the slit matrix is arranged on the upstream side of the exhaust. At this time, the flat sheet **2** and corrugated sheet **3** are joined at the non-slit matrix portions **1***a* and **1***b* near both ends of the slit matrix upstream and downstream sides with laser welding, resistance welding or brazing.

As illustrated in FIG. **1**, an outer casing **8** is shaped so that a clearance section S, which is an air insulation layer of which the radial length has a width of 1.5 mm almost equal to the corrugated sheet height in regard to the slit matrix on the upstream side of the metal catalyst carrier **10** is formed.

Eight openings **8***a* are formed at 45° intervals in the circumferential direction on the downstream side of the outer casing **8** that contacts the metal catalyst carrier **10**.

A laser beam is radiated from an outer portion other than the opening **8***a* portion at the downstream side end to weld the metal catalyst carrier **10** and outer casing **8**. Brazing can be used instead of a welding method. The metal catalyst converter **1** of the first embodiment is configured with this outer casing **8** and metal catalyst carrier **10**.

Numeral **11** in FIGS. **1** and **2** illustrates welding marks when laser welding is done. To prevent welding cracks in the foil material caused by the heat capacity difference in the foil material and outer casing **8** during laser welding, the outermost layer of the metal catalyst carrier **10** uses two layered corrugated sheets **3**. When brazing, flat plates should be used to ensure a sufficient welding area.

The disc-shaped flange **12** is welded and fixed to the upstream side of the outer casing **8** where the space portion S is formed. **13** illustrates the welding mark. This outer casing **8** and flange **12** are made of heat-resistant stainless steel SUS430 (Japanese Industrial Standard), and the same material is used for both portions. By using the same material for the flat sheet **2** and corrugated sheet **3**, a better weld-ability can be achieved.

To ensure a high weld-ability when welding outer casing **8** and flange **12**, an oxidation film is formed on the welding

surface by γ-Al_2O_3 coating described later. This oxidation film should be formed before the catalyst holding process.

Next the method for holding the catalyst in the honeycomb body and obtaining the metal catalyst carrier **10** will be described.

The metal catalyst carrier **10** is made by heating a honeycomb body to which the outer casing has been welded at 800° to 1299° C. for one to ten hours and precipitating an Al oxidant on the metal surface of the honeycomb. The body is then impregnated in slurry containing γ-Al_2O_3, and is baked.

Then the body is re-baked in a water-solution in which a catalyst metal such as Pt or Rh has been dissolved. In this case, the heat treatment before the γ-Al_2O_3 coating is done to suppress the peeling of the γ-Al_2O_3 coat and is a process to generate alumina whiskers on the metal foil and increase the foil surface area on the honeycomb body. A high reliability can be achieved with this process.

Next, by welding the outer casing **8** to which the flange **12** has been installed to the metal catalyst carrier **1**, the metal catalyst converter **1** can be used as a catalyst converter that can be installed in the exhaust gas passage of an automobile.

This metal catalyst converter **1** is fixed and held in the exhaust manifolds **6**a and **6**b as illustrated in FIGS. **6** and **8**. In other words, the flange **12** coupled and fixed with the metal catalyst converter **1** between the exhaust manifold installation flange **14***a* and start catalyst installation flange **15***b* via gasket **15** is fixed and held by bolt **16**, and the metal catalyst carrier is fixed and held in the exhaust manifolds **6***a* and **6***b*. In the first embodiment, engine **5** is a V8 4000 cc engine as shown in FIG. **7**. The eight exhaust manifolds led out from this engine **5** are grouped in groups of four manifolds to create the exhaust manifolds **6***a* and **6***b*. In the middle of each exhaust manifold **6***a* and **6***b*, a metal catalyst converter **1** fixed and held and a start catalyst **7**, a ceramic monolithic catalyst carrier having a capacity of 1300 cc, is arranged on the downstream side.

The start catalyst **7**, a monolithic catalyst carrier, is fixed and held with a wire net or ceramic fiber mat **18** in the outer casing **17** for the start catalyst. The downstream side flange **19** and exhaust pipe flange **20** for the start catalyst are coupled and integrated by bolt **21**. After the exhaust pipe **22** is centralized into one at the downstream side, a 1000 cc main catalyst (not illustrated) is arranged.

Next, the method for manufacturing the metal catalyst carrier **10** will be described. FIG. **9** illustrates the winding device **35** that slits the flat sheet **2**, forms the corrugated sheet **3**, winds the flat sheet **2** and corrugated sheet **3**, and laser welds the metal catalyst carrier **10**.

FIG. **10** is the front view of the winding device **35** that winds and laser welds the flat sheet **2** and corrugated sheet **3**. FIG. **11** is a plane view and FIG. **12** is a view from the right side. First, the material foil **23***a* and **23***b* are prepared at the left and right sides of the winding device **35**.

The material foil is guided from the material foil **23***a* and **23***b* set at the left and right sides, and the slits **4** are formed on both material foils by the press machine **24**. After that, the material foil **23***a* is corrugated by the corrugating rollers **25***a* and **25***b*, and finally, the corrugated sheet **3** and flat sheet **2** are wound to the designated dimension to obtain the metal catalyst carrier **10**.

At this time, the flat sheet **2** and corrugated sheet **3** are laser welded by the Y.A.G. laser welding machine **30** from the top and bottom at the crest and root. Numerals **31***a* and **31***b* are the laser displacement gauges for detecting the welding section. **31***a* is the laser projection section, and **31***b* is the reception portion. Numeral **32** is an optical fiber cable used to branch the laser beam radiated from the Y.A.G. laser welding machine **30**.

The actual winding and laser welding methods will be described in the following section.

The flat sheet **2** is guided to the center of the winding machine **35** by the flat sheet guide **33**, and the corrugated sheet **3** is guided to the center by the corrugated sheet guide sheet **34**. These are then guided to guide sheet **39** by the tension rollers **36** for the flat sheet **2** controlling, and the tension rollers **37** and **38** for the corrugated sheet controlling. This guide sheet **39** is driven by the motor **40** illustrated in FIG. **11**, and the flat sheet **2** and corrugated sheet **3** are wound by being laminated.

At this time, the flat sheet **2** and corrugated sheet **3** are laser welded by the Y.A.G. laser **30** while being wound. **41** is the laser radiation port. Here in FIG. **10**, an example where the laser beam from each laser welding machine **30** is branched into two by the optical fiber cable **32** and the flat sheet **2** side and corrugated sheet **3** side are each welded by two radiation ports 41 was illustrated. However, the number of branches can be increased as necessary.

The laser welding is done at the contacts of the flat sheet **2** and corrugated sheet **3** crests, so accurate position detection is required. For this purpose, the winding device **35** has the three laser displacement sensors **42**, **43** and **44** to detect the laser welding position. These three laser displacement sensors **42**, **43** and **44** incorporate compact laser displacement sensors set inside the same lens of the projecting and receiving portions. However, a non-contact sensor such as an overcurrent type displacement sensor or a contact type displacement sensor can be used instead of the laser displacement sensor.

The servomotor (not illustrated) is driven according to these detection signals, and the X-Y table **45** which fixes the laser radiation ports is moved accordingly. In other words, the laser displacement sensor **42** detects the gap between the laser radiation port **41** and metal catalyst carrier **10**, and the detection signal is sent to the servomotor (not illustrated). The laser displacement sensor **43** detects the gap between the laser radiation port **41** and the corrugated-shape valley formed in the corrugated sheet **2**, and sends the detection signal to the servomotor (not illustrated). The laser displacement sensor **44** detects the position of the corrugated-shaped crest formed in the corrugated sheet **2** at a position always deviated a half pitch and sends the detection signal to the servomotor (not illustrated). The laser displacement sensors **42**, **43** and **44** detect the portions where the peak of the corrugated-shaped crest formed in the corrugated sheet **3** and the flat sheet **2** are detected, and sends the detection signal to the servomotor (not illustrated). Then based on these detection signals the position of the X-Y table **45** is moved accordingly.

With the above control, the winding device **35** can accurately laser weld the crest of the flat sheet **2** and corrugated sheet **3**. The flat sheet **2** and corrugated sheet **3** are wound, the slit **4** is formed on only one end, and the flat sheet **2** and corrugated sheet **3** are laser welded at the designated positions to obtain the metal catalyst carrier **10**.

Next, the functions of the first embodiment will be described. After the engine **5** starts, the exhaust gas emitted from each cylinder's exhausting process flows through the exhaust manifolds **6***a* and **6***b*, and collides with the slit matrix positioned at the upstream side of the metal catalyst carrier **10**. As a result, the temperature of the slit matrix rises the most rapidly because the heat capacity is small due to the formation of the slits formed on the slit matrix, and because the slit matrix is insulated from the outer casing **8** by the air layer.

The following three points also contribute to the efficient rising of the temperature achieved due to the shape of the slit matrix, which is the low heat capacity area, having multiple openings formed the multiple slits.

First, as the cross-sectional area of the heat transfer portion is small and passage is longer in the axial direction of the metal catalyst carrier **10**, the downstream area of the slit matrix being heated can suppress the transfer of heat.

Secondly, in the same manner as the first point, due to the formation of the slit matrix, the contact area of the flat sheet **2** and corrugated sheet **3** in the radial direction of the metal catalyst carrier **10** is reduced, so the transfer of heat toward the outer casing can be reduced.

Thirdly, the slit matrix functions to mix the flow of the exhaust gas and thus the heat transfer efficiency can be increased.

The metal catalyst carrier **10** and outer casing **8** are joined near the downstream side end and is fixed to the exhaust pipe at the upstream portion so the passage of heat radiation transferred from the outer casing to the exhaust pipe is extremely long. In turn, the heat radiation amount is extremely small.

The reactionary heat caused by the oxidation reaction of HC and CO in the exhaust gas is transferred to the downstream side to help the temperature of the downstream side to rise.

Furthermore, the downstream side on which non-slit matrix portion is formed has a heat transfer that is larger in the radial and axial direction compared to the upstream side that has the slit matrix, and thus the heat transfer speed can be increased. In other words, the entire area of the downstream side can quickly raise the catalyst to the active temperature.

Due to the above reasons, within 15 to 16 seconds after engine **2** is started the entire area of the metal catalyst converter **1** can be activated. In the same way, the start catalyst **7** arranged in the direct downstream from the metal catalyst converter **1** is successively activated from the near the upstream side by the high temperature exhaust gas that passes through the metal catalyst converter **1**.

In the first embodiment, even if a large volume of exhaust gas flows when the engine **2** is heavily loaded, approximately 80% or more of the HC and CO in the exhaust gas can be purified by the metal catalyst converter **1** and start catalyst **7**.

Next, the characteristics of temperature rise by exhaust gas were compared between the metal catalyst converter according to the present invention and a conventional catalyst converter. In the comparative experiment, the metal catalyst converter according to the present invention and the conventional metal catalyst converter where configured as illustrated in FIG. 13. In other words, for the metal catalyst converter according to the present invention, a slit matrix was formed on only one end of the flat sheet and corrugated sheet as formed in the first embodiment. In the conventional metal catalyst converter (not illustrated) a band-shaped sheet metal with non-slit matrix portion on the metal catalyst converter **100** according to the present invention was employed.

Each metal catalyst converter was as illustrated in FIGS. **14**A and **14**B. The metal catalyst converter **100** according to the present invention had a column shape with a diameter of 66 mm and axial length of 78 mm as illustrated in FIG. **14**A. A slit matrix with a width of 26 mm was formed at a position separated 3 mm downstream from the upstream side of the metal catalyst converter.

The conventional metal catalyst converter had the same shape as the metal catalyst converter **100** according to the present invention but without the slit matrix as illustrated in FIG. **14**B.

These metal catalyst converters were installed at a distance where the exhaust gas emitted from the engine would reach approximately 300° C. within two to three seconds after the engine was started. To find the temperature rise of the metal catalyst converter, a temperature at the center of the metal catalyst converter 19 mm downstream in the axial direction from the upstream of each metal catalyst converter was measured. The results are illustrated in FIG. **15**.

In this figure A denotes a temperature of the exhaust gas at 20 mm upstream from the metal catalyst converters, B denotes a temperature inside the metal catalyst converter according to the present invention, and C denotes a temperature within the conventional metal catalyst converter. As can be seen in FIG. **16**, the metal catalyst converter according to the present invention reached approximately 300° C. in 4 to 5 seconds after the engine started, while it took the conventional metal carrier 8 to 9 seconds after the engine was started.

It can be confirmed that by forming a slit matrix at the upstream side of the metal catalyst carrier, a rapid temperature rise could be achieved. Although the slits have an approximate rectangular shape in the first embodiment, the present invention is not limited to this shape. Instead, rhombus shaped slits **46** as illustrated in FIG. **16** can be used.

Furthermore, the rectangular-shaped slits **47** can be arranged in a state that moves in parallel with the axial direction of the metal catalyst converter can also be used as illustrated in FIG. **17**. The slit matrix illustrated in FIG. **17** is achieved by rearranging the slit matrix illustrated in FIG. **4** for the first embodiment with interval H in the axial direction of the metal catalyst converter, and with interval D that crosses with the axial direction of the metal carrier. The particular difference with the slit matrix illustrated in FIG. **4** is that each slit is arranged to have a positional relation that is the same as the axial direction of the metal catalyst converter. This slit matrix is a row used to increase the rigidity of the metal catalyst converter, and although the axial direction heat transfer of the metal catalyst converter will drop somewhat, it is a level that does not pose a problem for the temperature rise performance. By using a slit matrix with a high characteristic frequency, the durability can be improved.

To achieve a sufficient strength (characteristic frequency) in the metal catalyst carrier, the aspect ratio h:W of the above slit should be 1:5 or less. Wherein, h is the length of the slit in the axial direction of the metal catalyst carrier, and W is the length of the slit in the direction perpendicular to the axial direction of the metal catalyst carrier.

The aspect ratio h:W of the slit matrix in the first embodiment is 1:2.5 (h=1.2, W=3), and is within the range of the ratio 1:5. This metal catalyst carrier was manufactured, and the characteristic frequency that is one index for expressing the mechanical strength was measured. A high value of 2 kHz or more was confirmed. After studying the characteristic frequency in various samples, it was found that the rigidity of the metal catalyst carrier became smaller and lower as the aspect ratio of the slit matrix increased. For example, in a metal catalyst carrier of which the slit matrix aspect ratio h:W was 1:6 (h=0.5: W=3), the characteristic frequency was less than 2 kHz.

As explained above, if the slit matrix aspect ratio h:W was 1:6 or more, the characteristic frequency was low, and the possibility that resonance would occur due to engine vibration increased. Thus, sufficient durability and reliability cannot be ensured.

On the other hand, in terms of purification performance, the dimensions of the slit matrix should have an opening percentage of 30 to 50% to ensure a sufficient purification performance immediately after starting. The opening percentage is calculated as follows:

[Opening percentage]=[Total of slit matrix hole portion surface area]+[Surface area when metal carrier is manufactured with same size and non-slit matrix portion].

In calculating, the thickness and side circumferential length is not considered.

The opening percentage of the slit matrix in the first embodiment is 46%, and is within the above 30 to 50% range. If the opening percentage is increased, the surface area of the metal catalyst carrier will drop, and on the other hand, if the opening percentage is too small, the heat capacity of the metal catalyst carrier will increase and the specified purification will not be obtained. As with the aspect ratio of the slit matrix, the slit matrix opening percentage was studied with various samples as shown in FIG. **39**. FIG. **39** shows a relationship between HC conversion efficiency and the opening percentage. HC conversion efficiency is required 50% or more. Further to secure enough strength the opening percentage must prevent from rising 50% or less. It is confirmed that the exhaust gas could be sufficiently purified immediately after starting the engine within the range of 30–50% of opening percentage. Consequently, the opening percentage should be set within 30–50%.

With the metal catalyst carrier presented in the first embodiment, a non-slit portion was provided near the foremost from of the slit matrix so that the metal flat sheet and corrugated sheets could be joined. The flat sheet **2** and corrugated sheet **3** in the metal catalyst carrier are joined at this section.

In other words, the foremost front end is formed as the welding margin for obtaining the strength of the metal catalyst carrier. Conventionally, the foremost front end of the metal catalyst carrier was a member that easily received the thermal energy of the exhaust gas, and it was preferred that there be no non-slit matrix portion in terms of performance. The axial length of the non-slit matrix portion was read with a barometer, and the range that did not affect the temperature rise and purification performance after starting was studied. As a result, it was found that if the area was 3 to 5 mm the performance would not be lost.

As explained above, after the temperature of the slit matrix rises, the heat is transferred to the non-slit portion formed at the rear end of the metal catalyst carrier.

As there is non-slit matrix portion formed on either the flat sheet or corrugated sheet at the non-slit area, the heat transfer speed is extremely fast, and the temperature of the portion rose in a short time.

However, if the non-slit matrix portion at the rear end of the metal catalyst carrier is too long, the temperature rise of the slit matrix will be obstructed. Thus, using the length of the non-slit matrix portion as a parameter, the optimum state was studied. As a result, it was found that if it was placed within the range of 5 to 60% from the upstream side of the metal catalyst carrier in the exhaust gas direction, the entire area could be activated in approximately 20 seconds after starting, and a sufficient purification performance could be achieved.

Furthermore, in the first embodiment, the radial direction length of the space formed between the outer casing and metal catalyst carrier was set to be approximately the same length as the crest height of the corrugated sheets that configure the metal catalyst carrier. This is because if the dimensions of the space formed between the outer casing and metal catalyst carrier is too large, the non-reacted gas will blow through the space. Thus, the space must be less than the crest height. In other words, if the space is less than the approximate crest height, a sufficient purification performance can be achieved as the catalyst is held also on the inner surface of the outer casing.

The durability of the metal catalyst converter **1** presented in the first embodiment will be described. The outer casing **8** which sheaths the metal catalyst carrier **10** is installed by fixedly welding at **11** to the metal catalyst carrier **10** on the downstream side of the slit matrix arranged on the flat sheet **2** and corrugated sheet **3**. Furthermore, the joining portion of the flat sheet **2** and corrugated sheet **3** is set to sandwich the slit matrix, but to not contact the outer casing **8** at the upstream and downstream sides.

Normally the thermal stress generated at the metal catalyst carrier **10** due to the cooling and heating cycle of the exhaust gas heat is caused by the difference in thermal expansion of the metal catalyst carrier **10** and outer casing **8**. In other words, it is generated by the large heat gradient near the outer most circumference of the metal catalyst carrier **10** due to the difference in linear expansion coefficient and difference in thermal capacity of the outer casing **8** and metal catalyst carrier **10**. However, with the configuration of the first embodiment, the heat gradient is small because of the opening portion or the space **8a** formed between the metal catalyst carrier **10** and outer casing **8** at the welding portion, so the thermal stress that occurs at the welding point can be suppressed.

To achieve this, the axial direction length of the space layer between the outer casing **8** and metal catalyst carrier **10** formed at the downstream side of the slit as the welding margin must be approximately 2 mm or more.

As the metal catalyst carrier **10** is connected to the outer casing **8** at only one end, the thermal stress that occurs due to the thermal expansion and contraction in the axial direction of the metal catalyst carrier **10** is small.

As multiple opening portions **8a** are arranged with an interval in the circumferential direction of part or all of the portion of the outer casing that contacts with the metal catalyst carrier **10**, the outer casing **8** thermally deforms according to the radial direction thermal expansion/contraction of the metal catalyst carrier **10**, so the reaction to this radial direction thermal expansion/contraction can be suppressed. With the above configuration and functions, the metal catalyst converter **1** according to the present invention has a durability that can withstand high temperatures exceeding 900° C. and the cooling and heating cycle with the outdoor air.

As a confirmation test, the metal catalyst converter according to the present invention was installed directly below the engine manifold. An engine cooling/heating cycle durability test wherein the temperature was changed between 100° C. and 900° C. in approximately 20 minute intervals was executed. It was confirmed that the converter did not break even after 1000 cycles, and thus the durability was confirmed. The flat sheet **2** and corrugated sheet **3** are alternately wound to obtain the metal catalyst carrier **10** in the first embodiment, but the present invention is not limited to this method. The metal catalyst converter can also be obtained by alternately laminating the flat sheet **2** and corrugated sheet **3**.

(Second Embodiment)

The temperature rise characteristics can be improved by forming the slits **4** on both the flat sheet **2** and corrugated sheet **3** as in the first embodiment. The problem with this

though, is that if the structure is used in an exhaust gas environment that exceeds 950° C., the strength at the sections where the slits **4** are formed in the flat sheet **2** and corrugated sheet **3** will be required more. Furthermore, as the tolerable strain of the material used to form flat sheet **2** and corrugated sheet **3** drops at high temperatures as illustrated in FIG. **18**, the shape of the slits tend to be restricted for durability and strength.

Thus, in the second embodiment, by providing slits on only the front end of the flat sheet **2** or the corrugated sheet **3** which faces the exhaust gas inflow direction, and non-slit matrix portion on the other the required strength can be achieved.

FIG. **19** is a development view of the metal catalyst carrier **48** according to the second embodiment.

The metal catalyst carrier **48** that holds the catalyst that generates an oxidation reduction reaction with the toxic elements of the exhaust gas in the honeycomb, is formed by alternately winding the flat sheet **49** that has non-slit matrix portion and the corrugated sheet **51** that has slits **50**.

With this type of structure, the metal catalyst carrier **48** having an outstanding durability can be achieved.

FIG. **20** is a characteristic view illustrating the specific comparison in specific temperature rise performance. In this figure, line **52** denotes the temperature of the gas that flows into the metal catalyst converter, line **53** denotes the metal catalyst carrier of the first embodiment with slit portion formed on both the flat sheet and corrugated sheet, line **54** denotes the metal catalyst carrier of the second embodiment with slit portion formed on only the flat sheet, line **55** denotes the metal catalyst carrier of the second embodiment with slit portion formed on only the corrugated sheet, and line **56** denotes the conventional metal catalyst carrier having non-slit matrix portion.

As is evident from FIG. **20**, the metal catalyst carrier with a slit portion formed in either the flat sheet or the corrugated sheet can achieve sufficient temperature rise characteristics compared with the conventional metal catalyst carrier. In the second embodiment, as the slit portion is formed only on the corrugated sheet side, the surface area per unit volume of slit portion can be increased thereby improving the holding density.

In the second embodiment, the slit portion was formed on the corrugated sheet and not on the flat sheet, but this is not limited. The slit portion can be formed on the flat sheet instead of the corrugated sheet. Furthermore, in the first embodiment the metal catalyst carrier was created by alternately winding the flat sheet and corrugated sheet, but the structure can also be created by alternately laminating the flat sheet and corrugated sheet.

(Third Embodiment)

The third embodiment according to the present invention will be described. FIG. **21** illustrates a simulation of the metal catalyst carrier **57** during winding.

The metal catalyst carrier **57** that holds the catalyst that creates an oxidation reduction reaction with the toxic elements of the exhaust gas in the honeycomb body and purifies the gas is configured by alternately winding the flat sheet **58** and corrugated sheet **59**.

The flat sheet **58** and corrugated sheet **59** have a width of 60 mm and thickness of 0.05 mm. Slit matrix **60** and slit matrix **61** are formed along 30.95 mm on one end of both sheets with differing slit aspect ratios. FIG. 22 is a partial enlargement view illustrating the shape of the slit matrix **60** and slit matrix **61** incorporated in the third embodiment.

The slits formed on flat sheet **58** have a width w of 3 mm, height h of 1.2 mm, and each slit is arranged with an interval H of 0.8 mm in the axial direction of the metal catalyst carrier, and an interval D of 1 mm in the direction that crosses with the axial direction of the metal catalyst carrier. The adjacent slits are offset each other by a distance of (W+D)/2 in the axial direction of the metal catalyst carrier.

In the same manner, the slit matrix **61** on the corrugated sheet **69** has a width w of 6 mm and height h of 1.2 mm. Each slit is arranged with an interval H of 0.5 mm in the axial direction of the metal catalyst carrier, and interval D of 1 mm in the direction that crosses with the axial direction of the metal catalyst carrier. Bumps are continuously formed with a pitch of 4.7 mm and height of 1.75 mm.

By alternately layering and winding this flat sheet **58** and corrugated sheet **59**, the metal catalyst carrier **57** according to the third embodiment in which the flat sheet **58** and corrugated sheet **59** having differing slit aspect ratios is achieved.

As explained above, the metal catalyst carrier **57** according to the third embodiment in which the flat sheet **58** with a small slit aspect ratio (h:w=1:2.5) and the corrugated sheet **49** with a large slit aspect ratio (h:w=1:5) are combined can be achieved.

Next, the operation, when the same type of outer casing as that in the first embodiment is welded to this metal catalyst carrier **57** to form the metal catalyst converter, and then arranging this in the exhaust manifolds ***6a*** and ***6b*** that are the exhaust gas passage illustrated in FIG. **6** for the first embodiment, will be explained.

After the engine **2** starts, the exhaust gas emitted from each cylinder's exhausting process flows through the exhaust manifolds ***6a*** and ***6b***, and collides with the slit matrix **60** and **61** positioned at the upstream side of the metal catalyst carrier **57**.

As a result, the temperature of the slit matrix **61** on the corrugated sheet **59** rises the most rapidly because the heat transfer passage is long and the heat transfer is smaller than the slit matrix **60** of the flat sheet **58**. The heat transfer of the slit matrix **60** on the flat sheet **58** in the third embodiment is approximately 1/25 of when there are no slits, and the heat transfer of the slit matrix **61** on the corrugated sheet **59** is approximately 1/10 of when there are no slits.

When the temperature of the slit matrix **60** and **61** reach the active temperature of the catalyst held by the metal catalyst carrier **57**, the purification of the exhaust gas starts. The activation of the catalyst at the downstream side of the flat sheet **58** and metal catalyst carrier **57** starts due to the reactionary heat and the heat transferred in the metal catalyst carrier **57**. The catalyst can be activated within the entire area of the metal catalyst carrier **57** within **15** to **16** seconds after engine **2** is started.

On the other hand, the pulsation of the exhaust gas colliding with the slit matrix **60** and **61** and the vibration of the engine **2** applies a considerable stimulus force (approximately 20 G) to the metal catalyst carrier **57**. By suppressing the slit aspect ratio (h:W) of the flat sheet **58** wound in the metal catalyst carrier, the resonance frequency of the metal catalyst carrier **57** can be increased to approximately four times of the stimulus frequency (approximately 500 Hz) which is the maximum primary explosion element of the engine **2**. As a result, the metal catalyst carrier **57** has an extremely durable structure.

In the third embodiment, the slit vertical horizontal ratio of the flat sheet **58** was set to be smaller than that of the corrugated sheet **59**, but this can be reversed. Furthermore in the third embodiment, rectangular slits were used, but this is not limited, and the rhombus shape illustrated in FIG. **16** for the first embodiment or the wavy shape illustrated in FIG. **17** can be used.

As explained according to this invention by using differing slit shapes on the corrugated sheet and flat sheet, and by using differing aspect ratios for the slit portions, the characteristics of the temperature rise characteristics and the vibration resistance characteristics can be changed. In the third embodiment, the flat sheet **58** and corrugated sheet **59** were laminated and wound to create the metal catalyst carrier **57**. However, the metal catalyst carrier **57** can also be created by simply laminating the flat sheet and corrugated sheet.

(Fourth Embodiment)

The fourth embodiment relates to the method of manufacturing the honeycomb body that is the metal catalyst holder by holding the catalyst. In the first and second embodiments, the axial length of the corrugated sheet and flat sheet that configure the honeycomb body were equal. When manufacturing this honeycomb body, the flat sheet and corrugated sheet must be alternately laminated and wound and the peak of the corrugated sheet welded to the flat sheet as illustrated in FIGS. **9** to **12** for the first embodiment.

When performing laser welding for this, the welding position must be accurately detected, and the laser beam must be radiated at the peak of the corrugated sheet to be welded. However, if the flat sheet is wound on the outer circumference of the corrugated sheet and welding is done, the peak must be detected through the flat sheet, and thus, detection wit the laser displacement sensor is difficult. With the overcurrent-type displacement sensor, the waves of the corrugated sheet must be detected through the flat sheet. However, as the output signal gain is small precise detection is difficult. In the fourth embodiment an example in which the welding position is easily detected by using a honeycomb body in which at least one end of the corrugated sheet in the honeycomb carrier is protruding from the flat sheet is presented. FIG. **23** illustrates an example in which the corrugated sheet is protruding from the flat sheet at the upstream side end. FIG. **24** illustrates when the corrugated sheet protrudes from the flat sheet at the downstream side end.

According to the honeycomb body **62** or **63** present in the fourth embodiment, the peak of the corrugated sheet, which is the welding position, always appears at the surface during laser welding. As the peak of the corrugated sheet that is to be welded only needs to be detected, the detection method is easy and the precision is improved.

Furthermore, the corrugated sheet always appears at the surface in the fourth embodiment, so detection is easy even with a contact-type displacement sensor other than the non-contact type displacement sensor. For example, a gear having a direct corrugated sheet shape can be installed on a rotary shaft such as an encoder and rotated with the corrugated sheet. Then, the welding position can be detected with the output signal.

(Fifth Embodiment)

The metal catalyst carrier **64** that holds the catalyst in the honeycomb body according to the fifth embodiment is illustrated in FIG. **25**.

As with the first embodiment, the metal catalyst converter **64** has an outer casing installed to a metal catalyst carrier **66** formed by winding a corrugated sheet and flat sheet (not illustrated) on which slit matrix **65** is formed only on the upstream side of the exhaust gas passage.

However, the difference with the metal catalyst converter **1** according to the first embodiment, is that the number of corrugated sheet and flat sheet windings on the downstream side of the exhaust gas passage excluding the slot row on the metal catalyst carrier exceeds the number of flat sheet and corrugated sheet windings on the slit matrix **65** portion. Because of this, the diameter of the metal catalyst carrier **66** is larger on the area where the slit matrix is not formed on the downstream side of the exhaust gas passage than on the area where the slit matrix is formed on the upstream side.

By configuring this type of metal catalyst carrier **66**, an outer casing **67** in which a clearance S is formed in the small range between the metal catalyst carrier **66** and the casing **67** slit matrix **65** can be achieved without the swaging processing used to deform the diameter of the outer casing **8** in the first embodiment.

As with the first embodiment, in this metal catalyst carrier **64**, the outer casing **67** is joined to the section where the slit matrix **65** that is the downstream side of the exhaust gas passage of the honeycomb carriers not formed. Flange **68** is provided at the upstream side end of the exhaust gas passage of the outer casing **67**.

FIG. **26** illustrates the configuration when the metal catalyst converter **64** of the fifth embodiment is arranged in the exhaust gas passage. As illustrated in FIG. **26**, the flange **68** provided on the outer casing is coupled and fixed via the gasket **15** between the exhaust manifold installation flange **14***a* and the start catalyst installation flange **14***b*.

The metal catalyst converter **64** is held and fixed so that a dimensional relation that creates the space portion S between the metal catalyst carrier **64** and exhaust manifold **6***a* is established. As in the first embodiment, with this configuration, the space portion S can be formed without using the large outer casing **67** that opposes slit matrix **65**. Thus, the same effect as the first embodiment can be achieved inexpensively.

(Sixth Embodiment)

FIG. **27** illustrates the metal catalyst converter **70** according to the sixth embodiment. This metal catalyst converter **70** is configured of the metal catalyst carrier **10**, which holds the catalyst in the honeycomb body, and the outer casing **72**.

As with the first embodiment, this metal catalyst carrier **10** is configured by winding corrugated sheets and flat sheets (not illustrated) on which slit matrix is formed only on the upstream side of the exhaust gas passage.

The metal catalyst carrier **10** is then joined with the outer casing **72** at the position where the slit matrix is not formed on the downstream side of the exhaust gas passage.

The difference between the sixth embodiment and fifth embodiment is that on the six embodiment a space portion is not formed between the outer casing **72** and metal catalyst holder **10**.

FIG. **28** illustrates the configuration when the metal catalyst converter **70** according to the sixth embodiment is arranged in the exhaust gas passage.

Even in the sixth embodiment, the flange **73** prepared on the outer casing **72** is coupled and fixed via gasket **15** between exhaust manifold installation flange **14***a* and the start catalyst installation flange **14***b*.

As with the fifth embodiment, the metal catalyst converter **70** is held and fixed so that a dimensional relation that creates the space portion S between the metal catalyst converter **70** and exhaust manifold **6***a* is established. Thus, the converter can be manufactured inexpensively in the same manner as the fifth embodiment.

(Seventh Embodiment)

FIG. **29** illustrates a simulation of the metal catalyst converter **75** according to the seventh embodiment. The outer casing that configures this metal catalyst converter **75** is configured of the first outer casing **76** and second outer casing **77** that have a divided semi-cylindrical shape struc-

ture, and of the fixing ring **78** that fixes these two casings. Stepped portions **76***a* and **77***a* are formed on the outer casings **76** and **77**. By forming these stepped portions **76***a* and **77***a*, the metal catalyst carrier **79** that holds the catalyst and outer casings **76** and **77** contact only on the downstream outer circumference of the metal catalyst carrier **79**. Thus, a space portion S is formed between the upstream outer circumference side of the metal catalyst carrier **79** and the outer casings **76** and **77**.

The outer casing **76** and **77** are joined to the metal catalyst carrier **79** with laser welding or brazing methods. By fitting a fixing ring **78** from the outer side of the split outer casings **76** and **77** so it contacts with the stepped portions **76***a* and **77***a*, the split outer casings **76** and **77** are fixed.

The diameter of the fixing ring **78** in the seventh embodiment is set to be the same or slightly smaller than the outer diameters **76** and **77** achieved when the outer casings **76** and **77** are fit together. Thus, the outer casings **76** and **77** are securely fixed by the fixing ring **78**.

Furthermore, the outer casings **76** and **77** are more rigidly fixed with the fixing ring **78** by welding the sides of the outer casings **76** and **77** and the inner circumference of the fixing ring **78**.

With the above configuration, the metal catalyst carrier **79**, outer casings **76** and **77** and the fixing ring **78** are coupled, and the metal catalyst converter **75** is created. The outer casings **76** and **77** and the fixing ring **78** can also be welded with arc welding or laser welding.

The clearance between the split outer casings **76** and **77** is plugged with the welding, etc. In this manner, the honeycomb carrier **79** is placed between the outer casings **76** and **77**, and then the fixing ring **78** is fit in from the outer circumference of the outer casings **76** and **77** so the positioning of the metal catalyst carrier **79** and outer casings **76** and **77**, and the fixing of the outer casings **76** and **77** can be done simultaneously. This allows the metal catalyst converter **75** to be achieved easily.

Furthermore, by splitting the outer casings **76** and **77**, when the metal catalyst carrier **79** is stored in the outer casings **76** and **77**, it does not need to be pressed in as when a whole outer casing is used. Thus, storage is possible without applying excessive compression stress, and the durability of the metal catalyst carrier **79** can be improved. The fixing ring **78** provided on the metal catalyst converter **79** can also be used as a flange.

Therefore as illustrated in FIG. **30**, the fixing ring **78** can be fit between the exhaust manifold **6***a* and the outer casing **17** for the start catalyst (not illustrated). With this type of configuration, the metal catalyst converter **75** can be installed in the exhaust manifold **6***a* without changing the configuration of the outer casings **76** and **77** and the start catalyst.

(Eighth Embodiment)

In the seventh embodiment, the outer casing that configures the metal catalyst converter **75** was split horizontally in the middle to create the outer casings **76** and **77**, and the clearance between the split outer casings **76** and **77** was plugged with welding, etc. However, in the eighth embodiment, the clearance is left slightly.

FIG. **31** illustrates the metal catalyst converter **80** according to the eighth embodiment. The opening portion **84** is formed on the joining surface of the first and second outer casings **82** and **83** which hold and fix the metal catalyst carrier **81** of the metal catalyst converter **80**. This opening portion **84** should be approximately 0.5 mm to 4 mm so that the gas that passes through the opening portion **84** does not blow out when the gas such as the exhaust gas passes through the metal catalyst carrier **81**. The outer casings **82** and **83** are then fixed by the fixing ring **85**.

According to the eighth embodiment, when the high temperature gas such as the exhaust gas flows into the metal catalyst carrier **81**, a reactionary heat occurs due to the held catalyst. Even if the metal catalyst converter **80** itself thermally expands at this time, the opening **84** formed between the outer casings **82** and **83** are pressed open, and the thermal strain that occurs between the metal catalyst converter **80** and outer casings **82** and **83** is reduced.

In other words, the opening portion **84** in the eighth embodiment has the same function and effect as the opening portions **8***a* formed on the outer casing **1** of the metal catalyst carrier **1** in the first embodiment.

Furthermore, the clearance and deformation that occur due to welding strain when welding and fixing the metal catalyst carrier **81** and outer casings **82** and **83** can be prevented, by that eliminating problems such as welding defects.

In the seventh and eighth embodiments, a configuration in which the structure was fixed to the exhaust pipe with a fixing ring was used, but the structure can be welded and joined directly to the exhaust pipe, or a flange-shaped fixing ring can be formed on both ends.

Furthermore, in said embodiments, the metal catalyst carrier was created by alternately winding flat sheets and corrugated sheets. However, the flat sheets and corrugated sheets can be simply layered to create a laminated metal catalyst carrier.

(Ninth Embodiment)

In the first embodiment, it was proposed that an outer casing **8** joined and fixed only at the outer most circumference of the downstream side be provided in the axial direction of the metal catalyst carrier **10** which holds the catalyst in the honeycomb body having slits on the upstream side in the axial direction.

The metal catalyst carrier **10** and outer casing **8** are fixed by welding at multiple points.

However, with this type of configuration, it is difficult to simultaneously weld multiple points, and thus, the points must be welded one at a time or several points at a time.

FIGS. **32**A and **32**B illustrate the problems that occur when welding the metal catalyst carrier **10** and outer casing **8** when there are no opening portions **8***a* formed on the outer casing presented in the first embodiment.

FIG. **32**A is a schematic side view illustrating the metal catalyst converter in which the metal catalyst carrier **10** and outer casing have been press-fit but not yet welded.

FIG. **32**B illustrates the schematic rear view when one point each on the outer casing **8** and metal catalyst carrier **10** have been welded.

As illustrated in FIG. **32**A, before welding, the fit of the metal catalyst carrier **10** and outer casing **10** is favorable without a clearance. However, when the welding is done one point at a time, as the outer casing **8** and metal catalyst carrier **10** materials are each heated to near the melting point, thermal deformation and thermal strain occur in the outer casing **8**. Because of this, problems such as the occurrence of clearances, welding defects and insufficient welding strength occur at the welding point of the outer casing **8** and metal catalyst carrier **10** as illustrated in FIG. **32**B.

In the ninth embodiment, an opening **8***a* on the rear downstream side of the metal catalyst carrier **10** and outer casing **8** is proposed. By providing this opening portion **8***a*, the thermal deformation that occurs the welding portion, which is one of said problems, can be reduced, and a

structure that can absorb the thermal expansion and contraction in the radial direction during the cooling and heating cycle of the metal catalyst carrier **10** can be achieved. The actual shape of this opening portion **8***a* will be described in the ninth embodiment.

FIG. **33** illustrates the shape of the opening portion **8**a in the ninth embodiment. In the ninth embodiment such as illustrated in FIG. **33**, when the relation of the distance a between the opening portions **8***a* and the axial length b of the metal catalyst carrier of the opening potion **8***a* is a≧b, the thermal deformation during welding of the metal catalyst carrier and outer casing and the thermal expansion and contraction in the radial direction during the cooling and heating cycle of the metal catalyst carrier can be easily absorbed.

This a×b portion functions as a beam configuration during the thermal load and obstructs the thermal expansion in the radius direction of the honeycomb body. Thus, the lower the axb portion rigidity is, the more easily the deformation can be absorbed.

In other words, the outer casing's axb portion that occurs with the thermal expansion in the radius direction of the honeycomb has a relation of b≧a, the rigidity can be lowered. Furthermore, if the metal catalyst carrier **10** is press-fit and assembled into the outer casing **8**, a pressing force will occur on the metal catalyst body **10** due to the slackening of the outer casing **8**, and a favorable joint can be established between the metal catalyst carrier **10** and outer casing **8**.

In the ninth embodiment, the shape of the opening portion **8***a* was a simple slit, but this is not limited and can be a shape as illustrated in FIGS. **34** to **36**. In FIG. **36** the opening portion shape was inclined in the axial direction, but this can also be a curved shape.

In FIG. **37**, in addition to the formation of the opening portion **8***a*, a groove portion **8***b* was formed in the circumferential direction to achieve the same effect as the above configuration.

(Tenth Embodiment)

In the first embodiment, flange **12** was provided on the outer casing **8** of the metal catalyst converter **1**, and the structure was held and supported with this flange **12**. However, in the tenth embodiment, a method for holding and fixing the structure by providing a flange **12** on the outer casing **8** will be described.

FIG. **38** illustrates the metal catalyst converter **86** according to the tenth embodiment. In FIG. **38**, numeral **17** is the outer casing for the start catalyst. The metal catalyst converter **86** is configured of the metal catalyst carrier **87** an outer casing **88** that does not have a flange to hold this metal catalyst carrier **87**.

The outer casing **88** is welded and joined to the metal catalyst carrier **87** at welding point **89** at the downstream side of the exhaust gas passage. All or part of the upstream side of the exhaust gas passage in this outer casing **88**, is welded by at least one point on the outer surface of the outer casing **88** within the axial direction range of the metal catalyst carrier **87** and space portion S. **90** indicates the welding point of the outer casing **88** and outer casing **17** for the start catalyst.

With the above configuration, the metal catalyst converter can be held and fixed without providing flanges on the outer casing, and the metal catalyst converter can be provided inexpensively.

The metal catalyst carriers and metal catalyst converters according to the present invention, can be incorporated to catalyst converters used without electrical conduction, and also for metal catalyst converters with a further outstanding temperature rise characteristics achieved by conducting the metal catalyst converter.

In concrete terms, metal catalyst carrier can be electrically conducted from the downstream side of the exhaust gas passage to the upstream side.

By incorporating the present invention, an inexpensive catalyst converter configured of a honeycomb body of which the temperature can be increased easily just with the heat of the exhaust gas and the catalyst carrier which holds the catalyst in the honeycomb body, which can raise the catalyst to the activation temperature in a short time, and which has sufficient strength can be provided.

What is claimed is:

1. A honeycomb body arranged in the exhaust gas passage of an engine, comprising;

at least one flat metal sheet;

at least one corrugated metal sheet superimposed with said flat metal sheet one over the other and defining a metal catalyst carrier having a plurality of axial gas passages to allow exhaust gas to flow axially from an upstream side to a downstream side of said gas passages, said flat metal sheet and said corrugated metal sheet each having an upstream portion and a downstream portion;

wherein said upstream portion is a low heat capacity area which is smaller in heat capacity than said downstream portion;

wherein said carrier is configured by alternately winding or laminating said at least one flat metal sheet and said at least one corrugated metal sheet, said low heat capacity area is configured of a slit matrix created by a plurality of rows of slits which are through-holes, and said rows of slits extend in a direction generally perpendicular to said gas passages.

2. The honeycomb body according to claim **1**, wherein each of said slits has an approximate rhombus shape or an approximate rectangular shape of which length h extends in an axial direction of said metal carrier and of which length w extends in the direction perpendicular to the axial direction of the carrier body, and each slit's aspect ratio h:w is 1:5 or less, and wherein the carrier is supported substantially solely at one end thereof.

3. The honeycomb body according to claim **1**, wherein adjacent slits in an axial direction of the metal catalyst carrier are offset by (W+D)/2, wherein W is the length of said slit in a direction perpendicular to the axial direction of the metal catalyst carrier and D is an interval between adjacent slits in said direction perpendicular to said axial direction.

4. The honeycomb body according to claim **1**, said slit matrix is formed by arranging each said slit so that adjacent slits of said slits in an axial direction of said carrier have an interval H an adjacent slits of said slits in a direction perpendicular to said axial direction of said carrier have an interval D, and wherein each said slit in each row is arranged to establish the same positional relation to said axial direction of said carrier.

5. The honeycomb body according to claim **1**, wherein an opening rate of said slit matrix is within the range of 30 to 50%.

6. The honeycomb body according to claim **1**, wherein at least one of said flat metal sheet and said corrugated metal sheet has a non-slit matrix portion in which no slits are formed at the upstream side of said gas passages; and wherein said carrier is supported substantially solely at one end thereof.

7. The honeycomb body according to claim 6, wherein a length of said non-slit matrix is 3 to 5 mm is axial direction of said carrier.

8. The honeycomb body according to claim 6, wherein said non-slit matrix is arranged within the range of 5 to 60% of an axial length of said carrier from an upstream side end of said carrier to exhaust gas downstream side direction.

9. The metal carrier according to claim 6, wherein said flat sheet and said corrugated sheet are mutually joined substantially at said non-slit matrix portion at said upstream side of said gas passages.

10. A catalyst converter comprising:

a catalyst carrier arranged in an exhaust gas passage of an exhaust pipe from an engine wherein catalyst that causes an oxidation reduction reaction with toxic element in exhaust gas emitted from said engine is held in said catalyst carrier, and wherein the catalyst carrier defines a low heat capacity area only at an upstream side of said exhaust gas passage, said area being smaller in heat capacity than a downstream portion of said catalyst carrier at a downstream side of said exhaust passage, and wherein an outer casing having an air insulation layer at an area corresponding to said low heat capacity area of said catalyst carrier is formed; and wherein said low heat capacity area of said catalyst carrier has a matrix of slits having openings formed by a plurality of row of slits that extend in a direction generally perpendicular to a direction of exhaust gas glow in said exhaust passage.

11. The catalyst converter according to claim 10, wherein a plurality of openings are formed in a row on said outer casing with intervals in a circumferential direction on at least part of a portion of the outer casing that joins with said catalyst carrier, and wherein said openings on the outer casing can thermally deform in a direction that said catalyst carrier radially expands and contracts.

12. The catalyst converter according to claim 10, wherein said catalyst carrier is configured by alternately winding or laminating metal flat sheets and corrugated sheets.

13. The catalyst converter according to claim 12, wherein a portion of said flat sheet and corrugated sheet joined with said outer casing is a non-slit matrix portion downstream of said slit matrix.

14. The catalyst converter according to claim 10, wherein said air insulation layer has a space that is 2 mm or more from foremost downstream side of said slit matrix to the axial downstream side of said catalyst carrier.

15. The honeycomb body according to claim 10, wherein each of said slits has an approximate rhombus shape or an approximate rectangular shape of which length h extends in an axial direction of said metal carrier and of which length W extends in the direction perpendicular to the axial direction of the carrier, and each slit's aspect ratio h:W is 1.5 or less, and wherein the carrier is supported substantially solely at one end thereof.

16. The honeycomb body according to claim 10, wherein adjacent slits in the direction perpendicular to the axial direction are offset by (W+D)/2, wherein W is the length of said slit in a direction perpendicular to an axial direction of the metal catalyst carrier and D is an interval of adjacent slits arranged in a direction perpendicular to said axial direction.

17. The honeycomb body according to claim 10, said slit matrix is formed by arranging each said slit so that adjacent slits of said plurality of slits in an axial direction of said carrier have an interval H and adjacent slits of plurality of slits in a direction perpendicular to said axial direction of said carrier have an interval D, and wherein each said slit in each row is arranged to establish the same positional relation to said axial direction of said carrier.

18. The catalyst converter according to claim 10, wherein an opening rate of said slit matrix is within the range of 30 to 50%.

19. The catalyst converter according to claim 18, wherein said catalyst carrier is configured by alternately winding or laminating metal flat sheets and corrugated sheets.

20. The catalyst converter according to claim 15, wherein a radial length of said air insulation layer formed between said slit matrix and said outer casing is less than the corrugation height of said corrugated sheets that form said catalyst carrier.

21. The catalyst converter according to claim 15, wherein a non-slit matrix portion is formed at an upstream side end of said flat sheet and corrugated sheet or at a foremost front end of said slit matrix, the metal flat sheet and corrugated sheet being joined substantially at said non-slit matrix portion.

22. The catalyst converter according to claim 21, wherein said non-slit matrix portion arranged at the upstream side end of said flat sheet and corrugated sheet is a length of 3 to 5 mm in the axial direction of said carrier.

23. The catalyst converter according to claim 21, wherein said non-slit matrix portion is arranged within the range of 5 to 60% of an axial length of said carrier from an upstream side end of said carrier to exhaust gas downstream side direction.

24. The catalyst converter according to claim 21, wherein only said non-slit matrix portion of said flat sheet and corrugated sheet is mutually joined; and wherein said carrier is supported substantially solely at one end thereof.

25. The catalyst converter according to claim 10, wherein said outer casing is joined with said catalyst carrier at a portion other than said matrix of slits, on a downstream side of said catalyst carrier.

26. The catalyst converter according to claim 10, wherein said outer casing is joined with said catalyst carrier adjacent to a downstream side of said catalyst carrier.

27. The catalyst converter according to claim 10, further comprising:

a outer casing flange of which one end is connected to an upstream side of said outer casing, an other end of the flange is fit between a pair of flanges projecting from the exhaust pipe so that said catalyst carrier is stored in the exhaust pipe by said outer casing flange.

28. The catalyst converter according to claim 10, wherein said catalyst carrier is stored in the exhaust pipe by joining the outer casing to an inner surface of the exhaust pipe adjacent to an upstream end of said outer casing.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 5,599,509

DATED : February 4, 1997

INVENTOR(S) : TOYAO et al.

It is certified that error appears in the above-indentified patent and that said Letters Patent is hereby corrected as shown below:

On the title page, item "[*] Notice: The portion of the term ...Disclaimed." to --[*] Notice: The term of this patent shall not extend beyond the expiration date of Pat. No. 5,648,050.--

Signed and Sealed this

Eighteenth Day of November 1997

Attest:

Bruce Lehman

BRUCE LEHMAN

Attesting Officer

Commissioner of Patents and Trademarks

US005436216A

United States Patent [19]

Toyao et al.

[11] Patent Number: 5,436,216

[45] Date of Patent: Jul. 25, 1995

[54] SELF-HEAT GENERATION TYPE HONEYCOMB FILTER AND ITS APPARATUS

[75] Inventors: **Tetsuya Toyao**, Toyoake; **Takeshi Matsui**, Toyohashi; **Tetsuya Nakamura**, Chiryu; **Atsushi Okajima**, Kariya; **Hiromasa Aoki**, Nagoya; **Senta Tojo**, Kariya; **Naoki Nagata**, Nagoya; **Shigeru Maehara**, Kariya; **Kanehito Nakamura**, Anjo, all of Japan

[73] Assignee: **Nippondenso Co., Ltd.**, Kariya, Japan

[21] Appl. No.: **121,588**

[22] Filed: **Sep. 16, 1993**

[30] **Foreign Application Priority Data**

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Sep. 14, 1993 [JP] Japan 5-229060

[51] **Int. Cl.**^{6} **B01J 35/04**

[52] **U.S. Cl.** **502/439**; 502/527; 423/213.2; 55/523; 55/DIG. 30; 422/173; 422/174; 422/177; 422/180

[58] **Field of Search** .... 502/439, 527; 423/213.2; 55/523, DIG. 30; 422/174, 173, 177, 180

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Primary Examiner—Anthony McFarlane
Attorney, Agent, or Firm—Cushman, Darby & Cushman

[57] **ABSTRACT**

A self-heat generating type honeycomb filter is mounted in an exhaust pipe line of an engine, and a plane plate and a corrugated plate are layered, then wound, and the first slit portion and second slit portion having openings, respectively, are formed between an up-stream and down stream side end portions of the plane and corrugated plates. An electric current is applied between the up-stream and down stream side end portions, to heat the first and second slit portions. Accordingly, a self-heat generation type catalytic converter capable of realizing both high resistance and low thermal capacity, and further ensuring a reduction in thermal conduction, and durability, and raising the temperature up to the sufficient level with less power consumption, can be provided.

11 Claims, 33 Drawing Sheets

FIG. 1

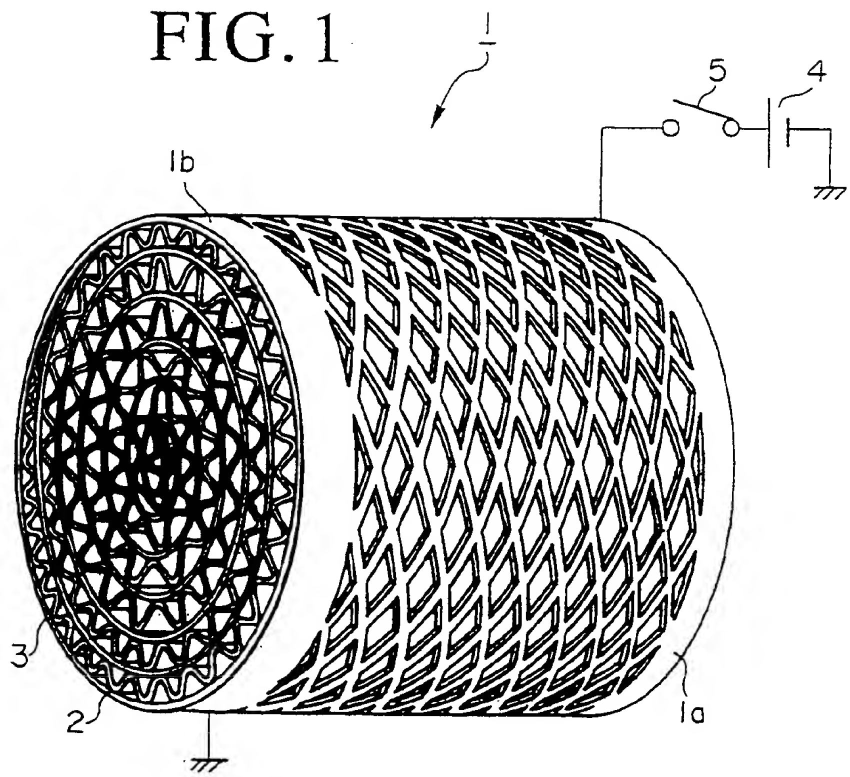


FIG. 2

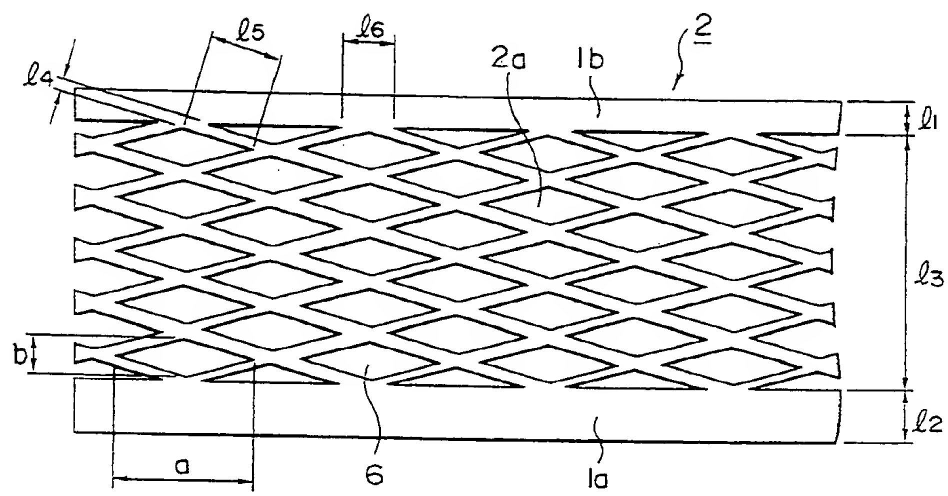


FIG. 3

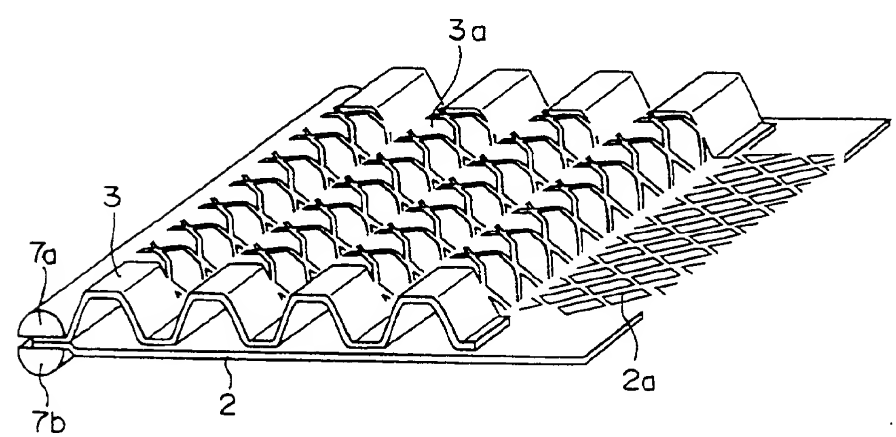
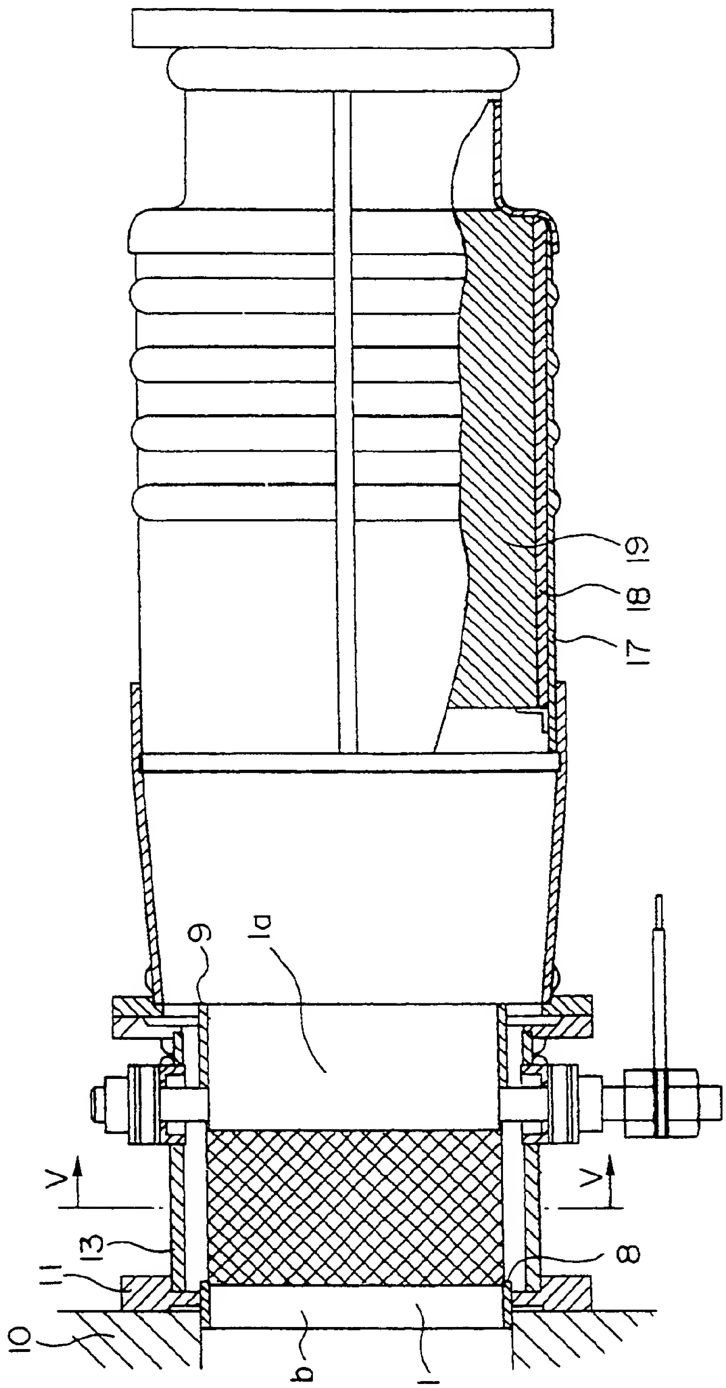


FIG. 4



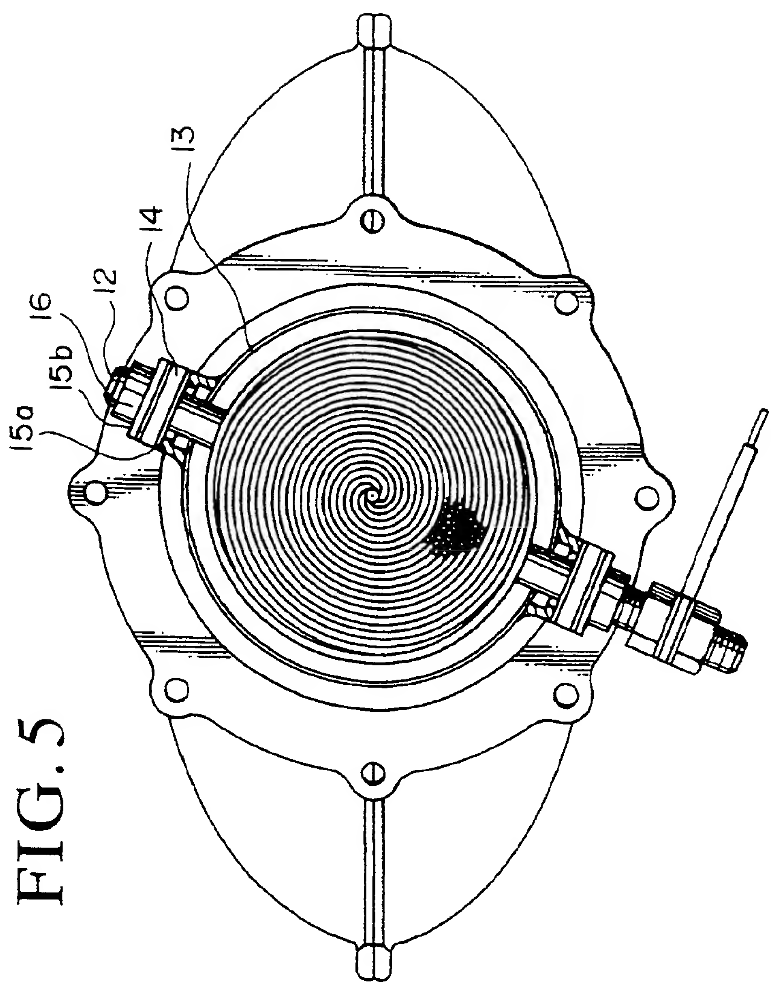


FIG. 5

FIG. 6

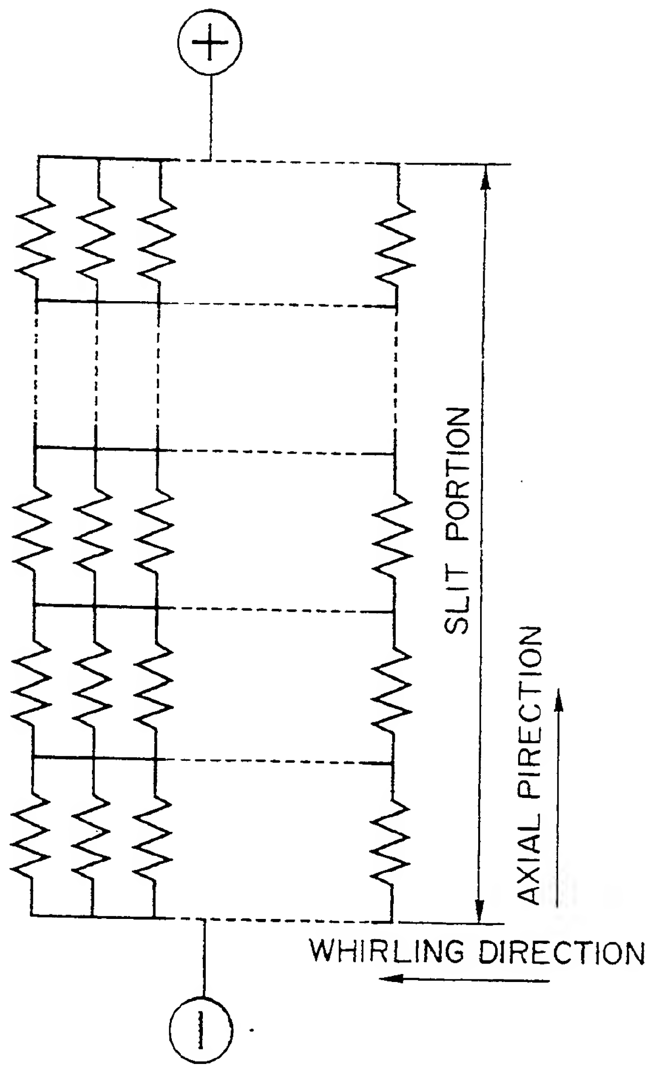


FIG. 7

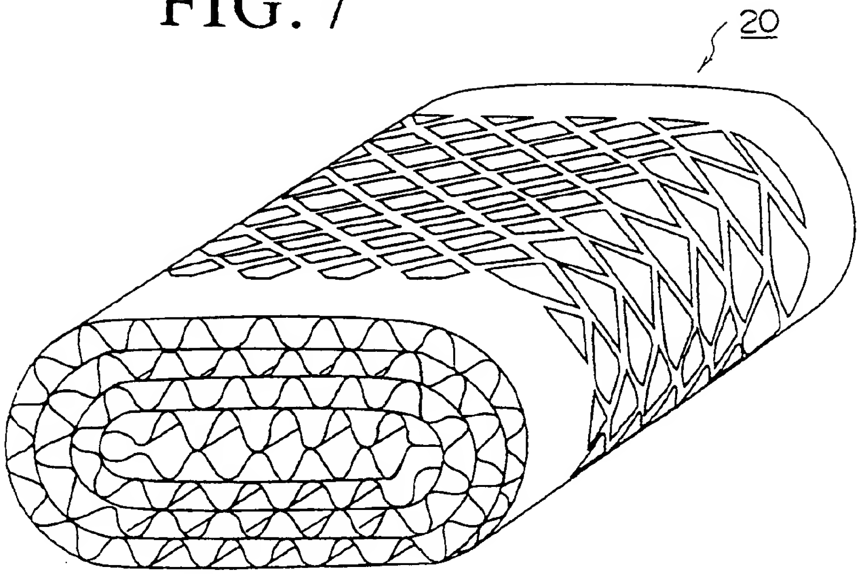


FIG. 8

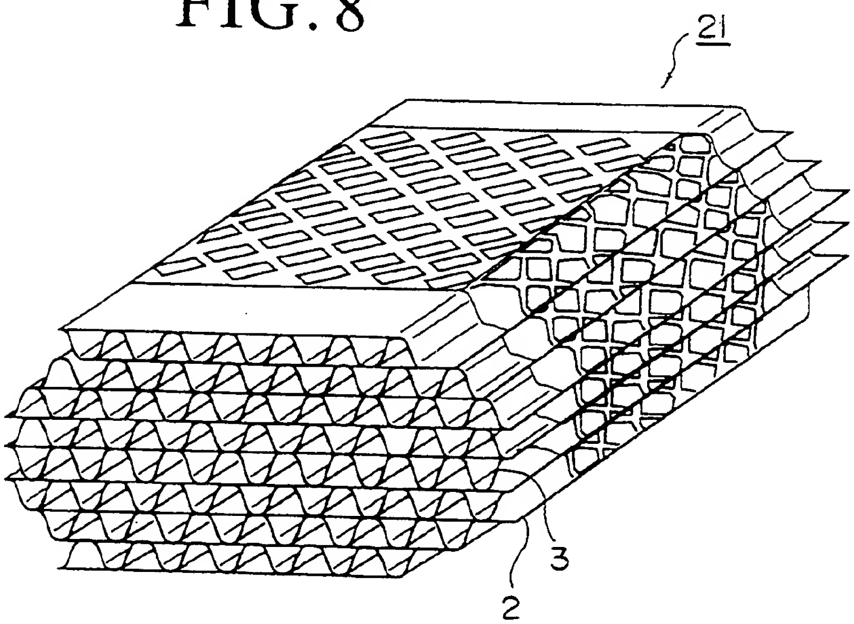


FIG. 9

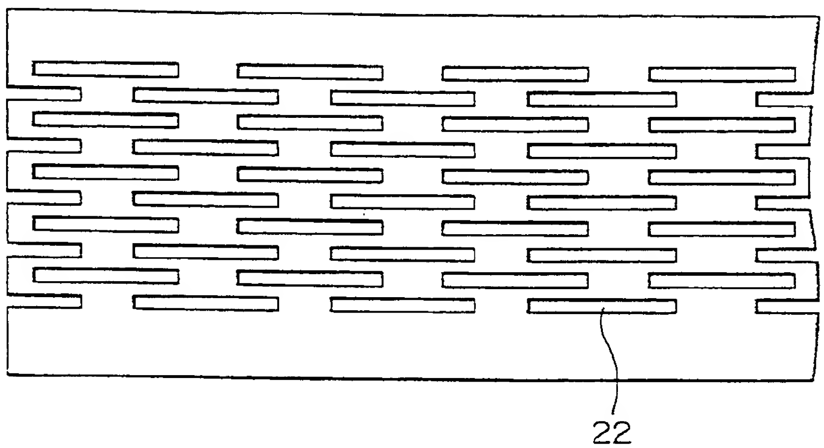


FIG. 10

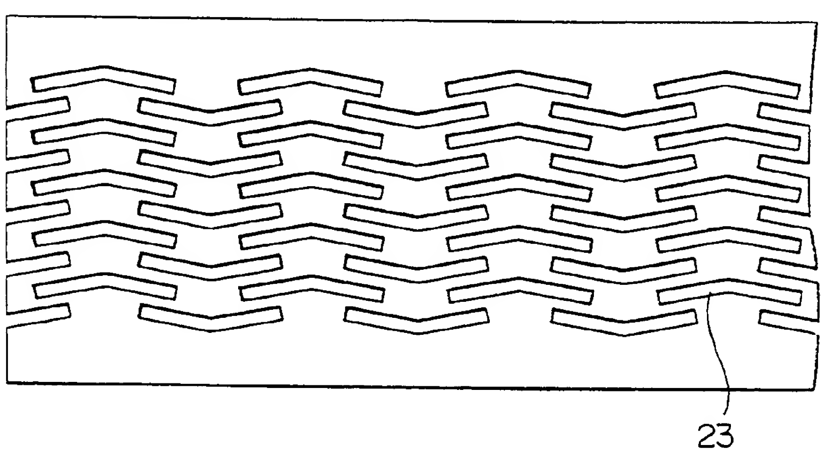


FIG. 11

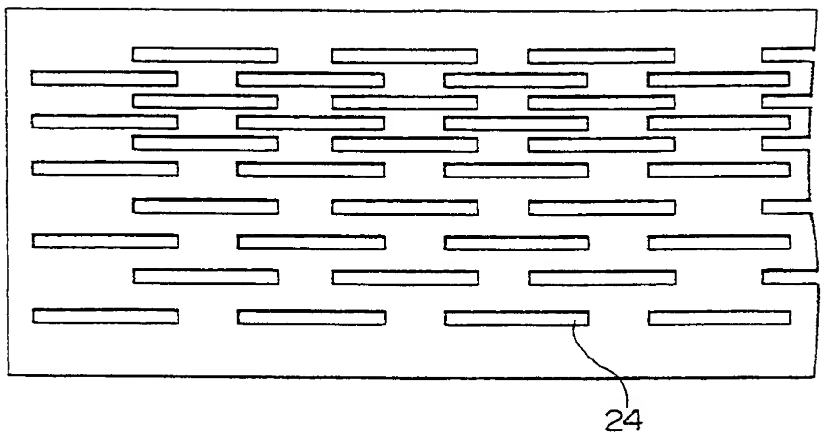


FIG. 12

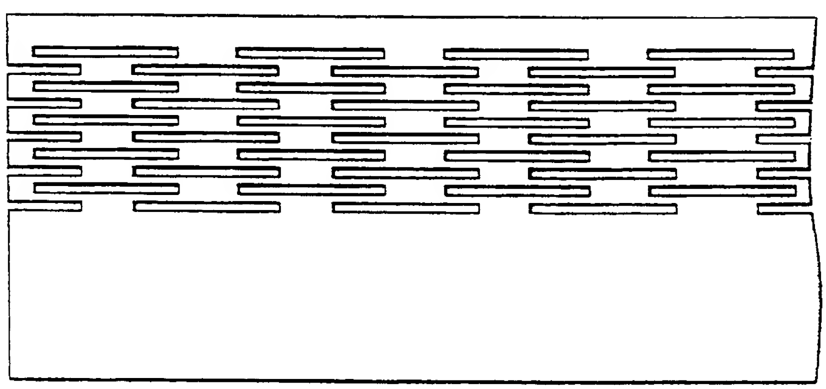


FIG. 13

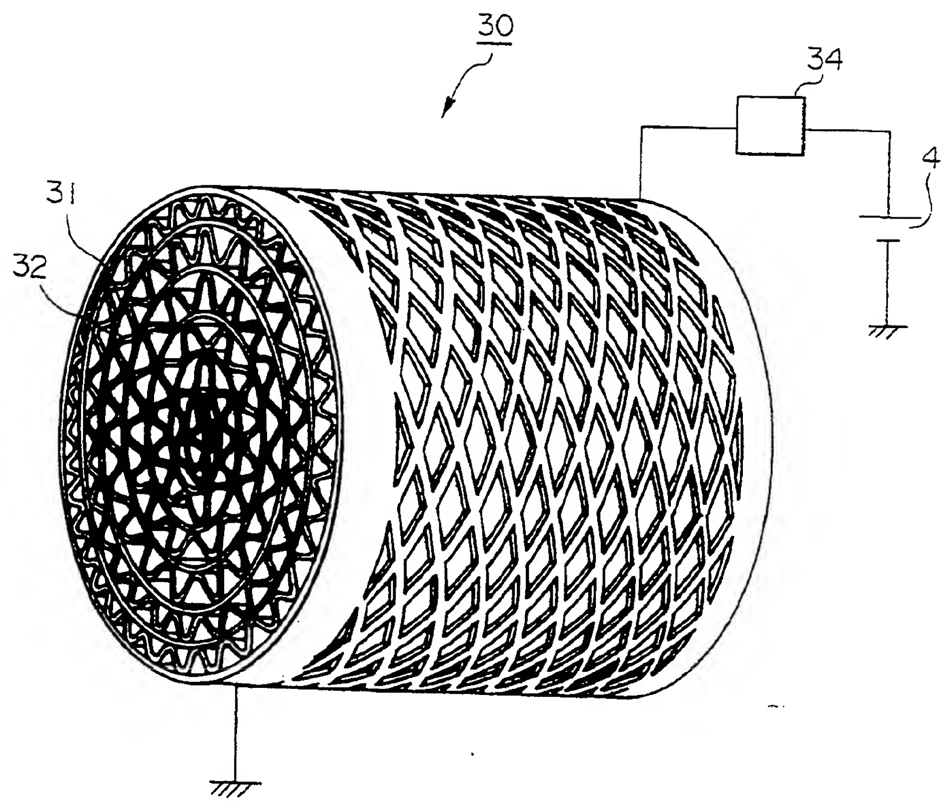


FIG. 14

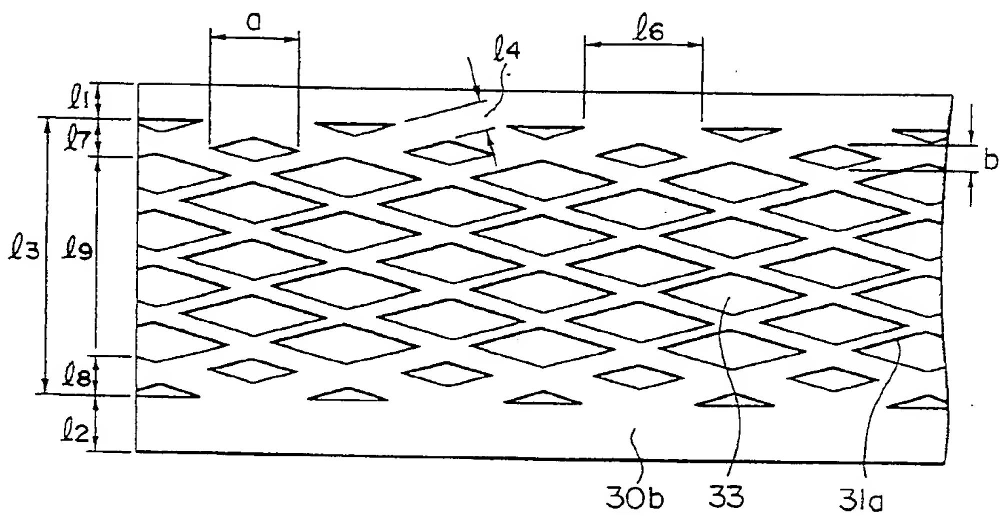


FIG. 15

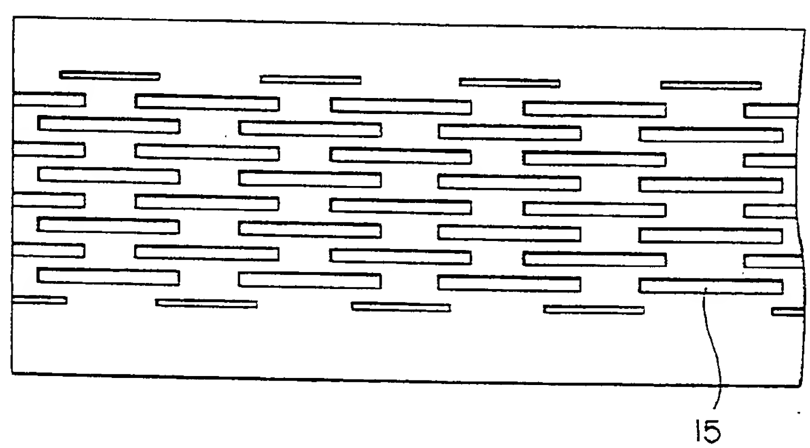


FIG. 16

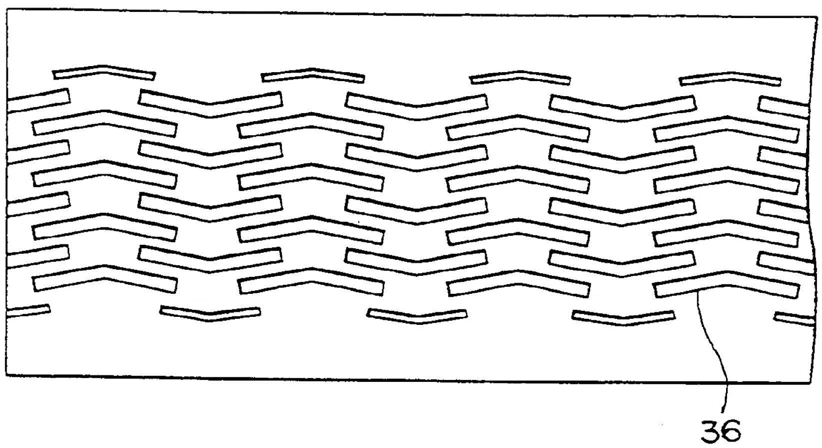


FIG. 18

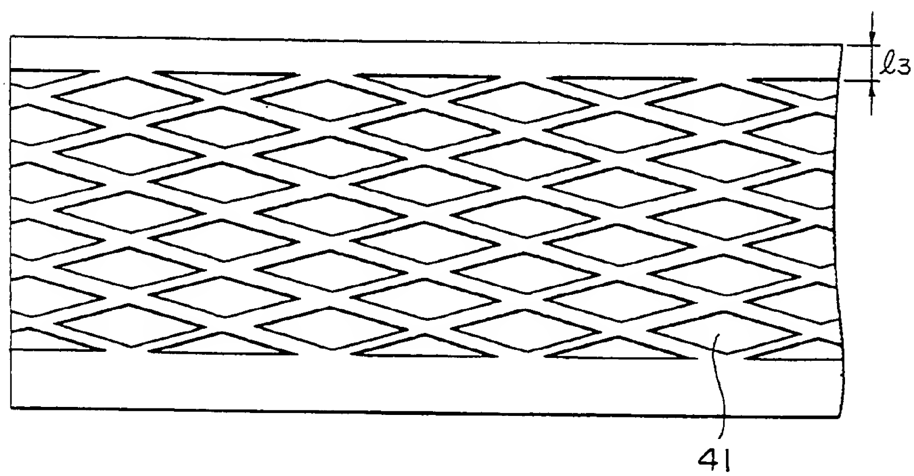
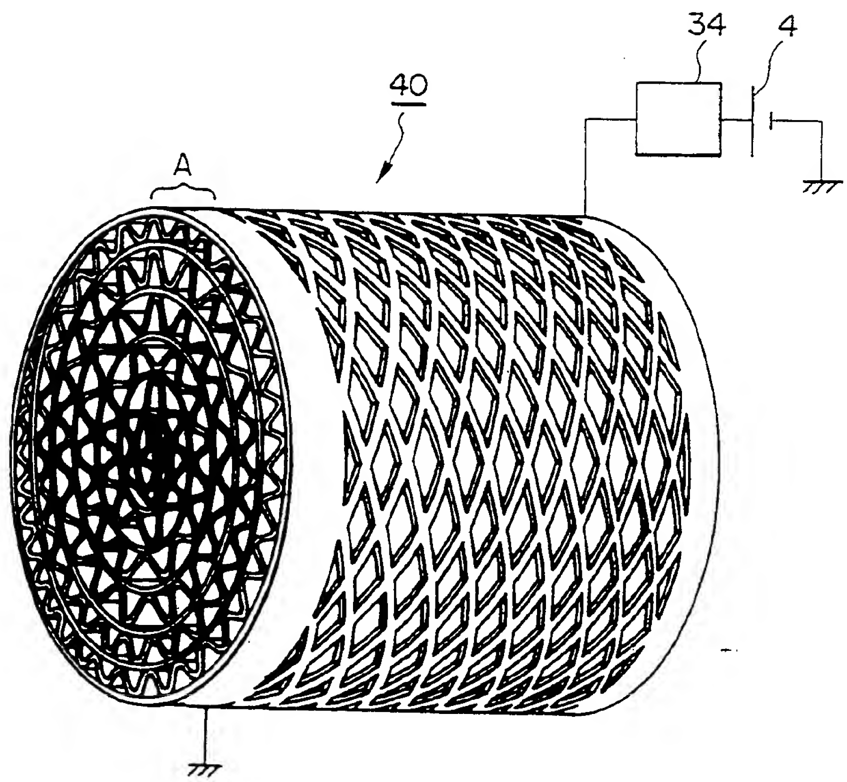


FIG. 17



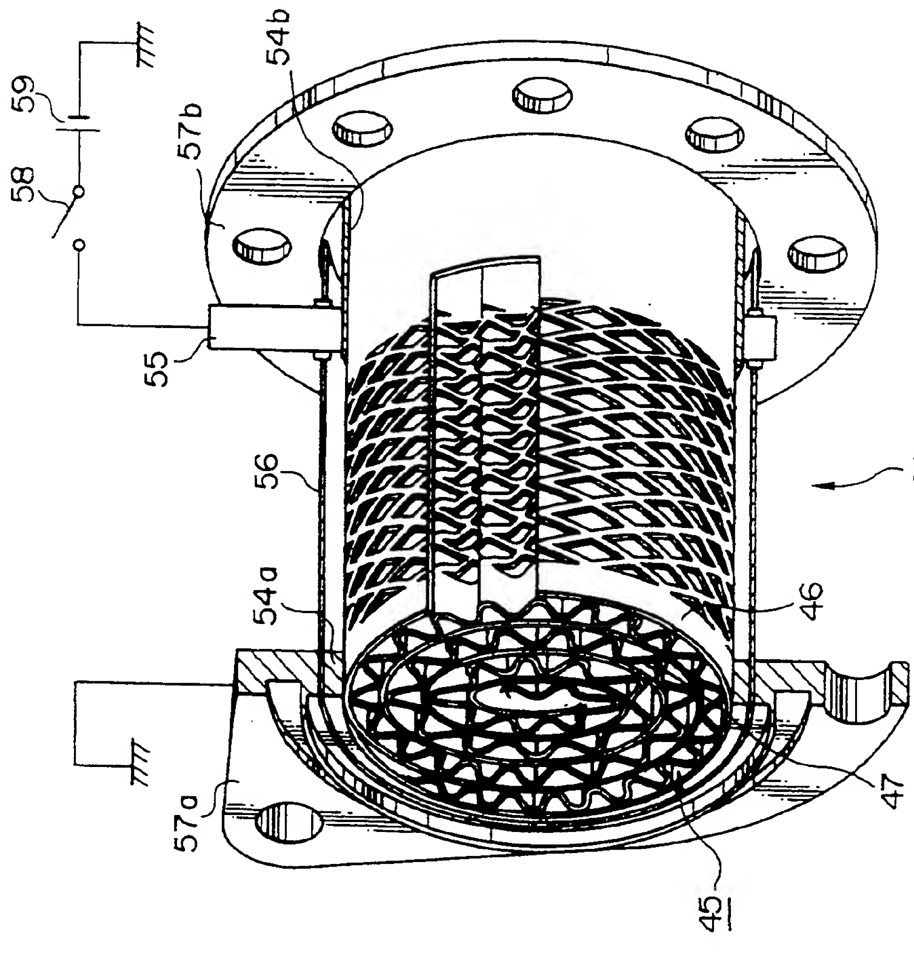


FIG. 19

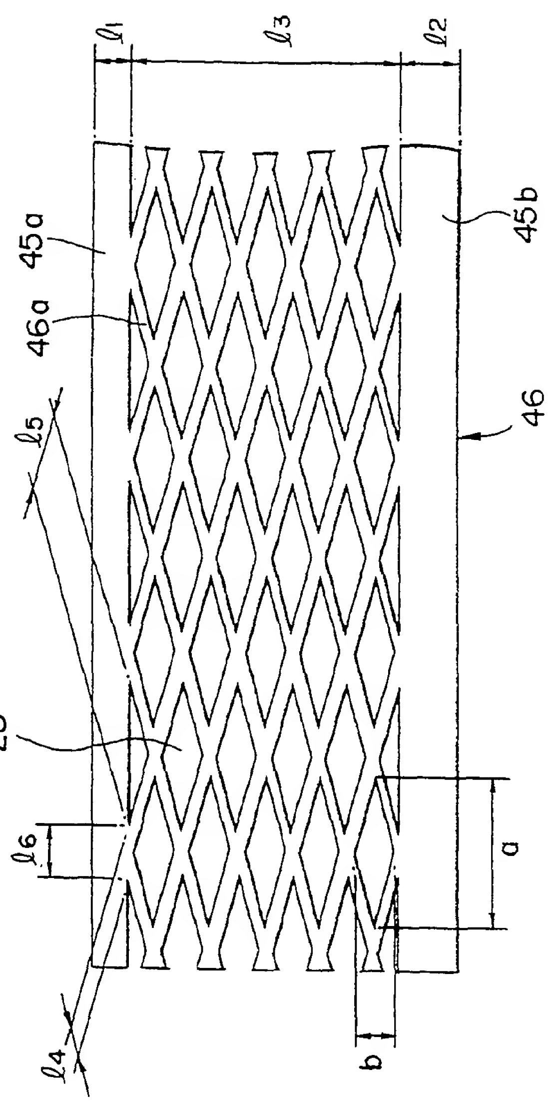


FIG. 20

FIG. 21

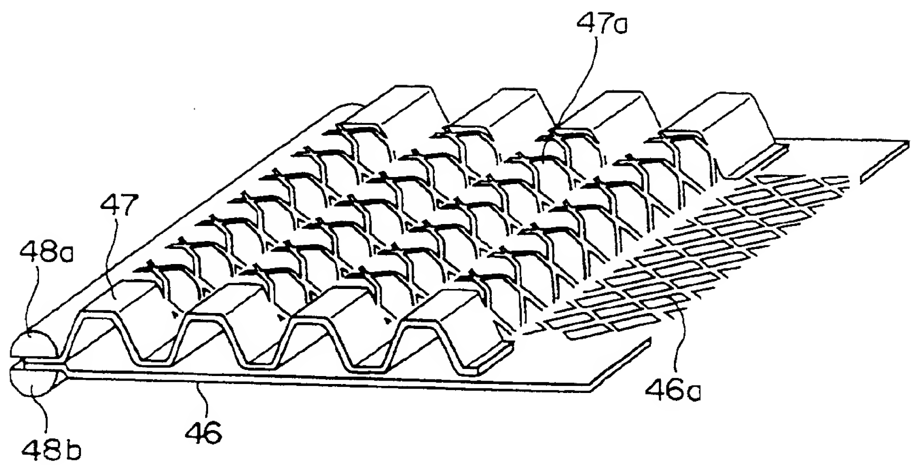
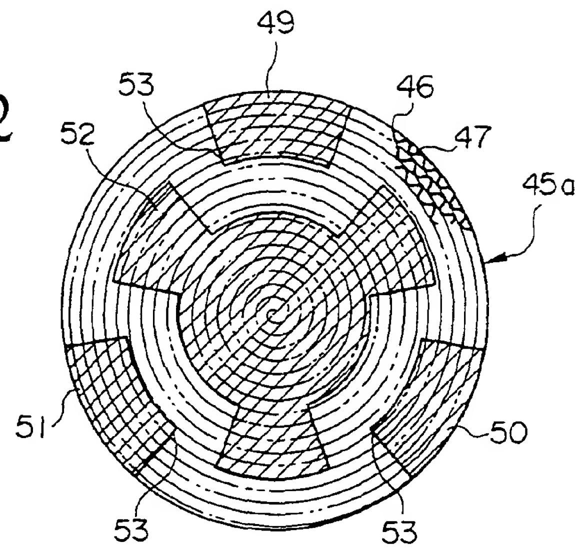


FIG. 22



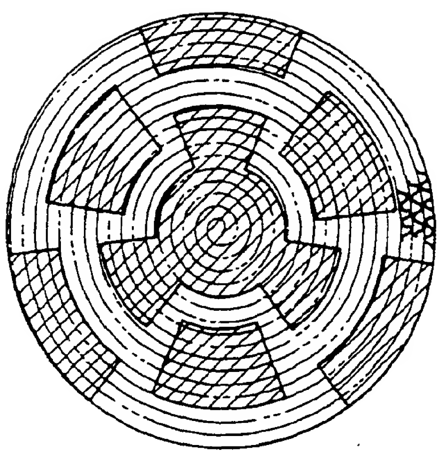


FIG. 23

FIG. 24

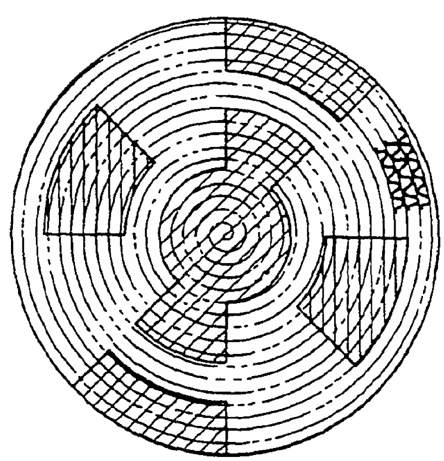


FIG. 25

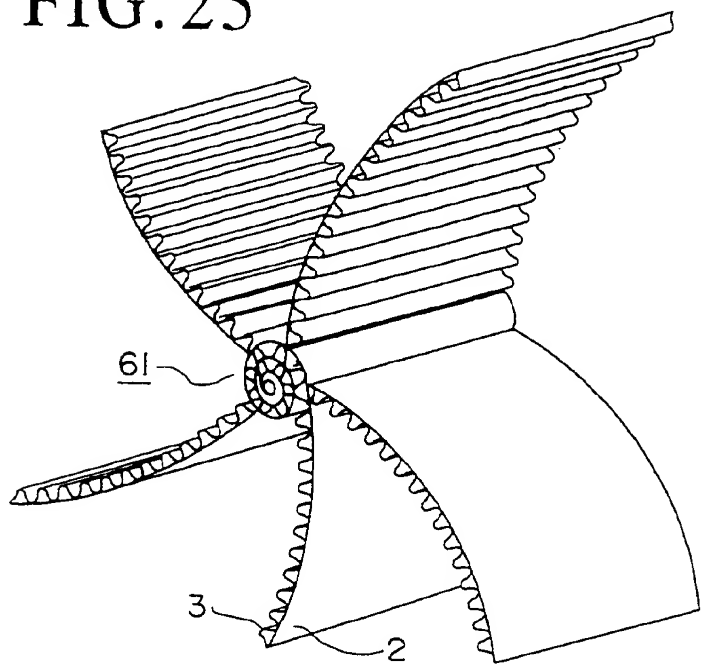


FIG. 26

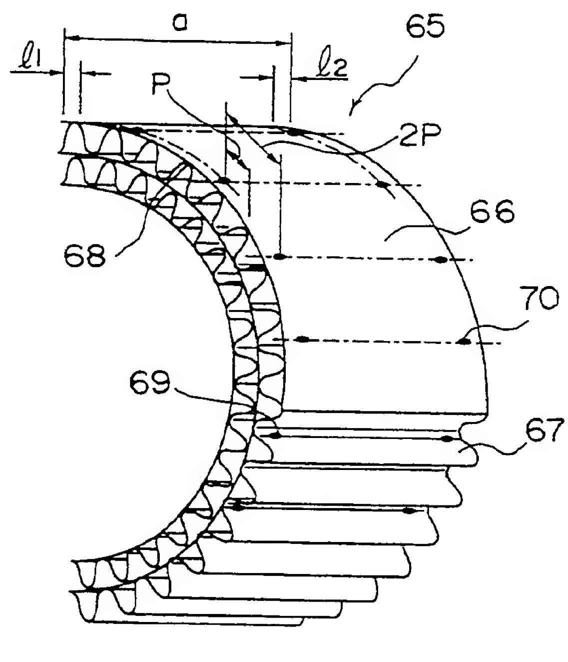


FIG. 27

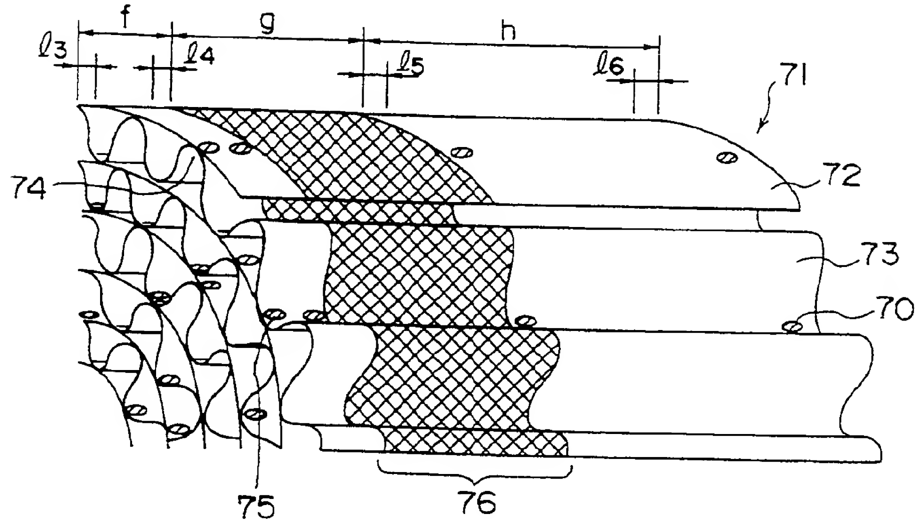
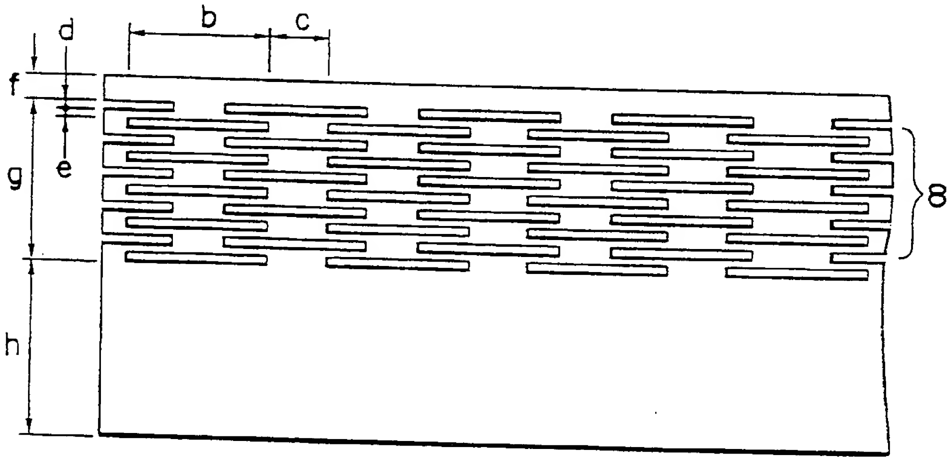


FIG. 28



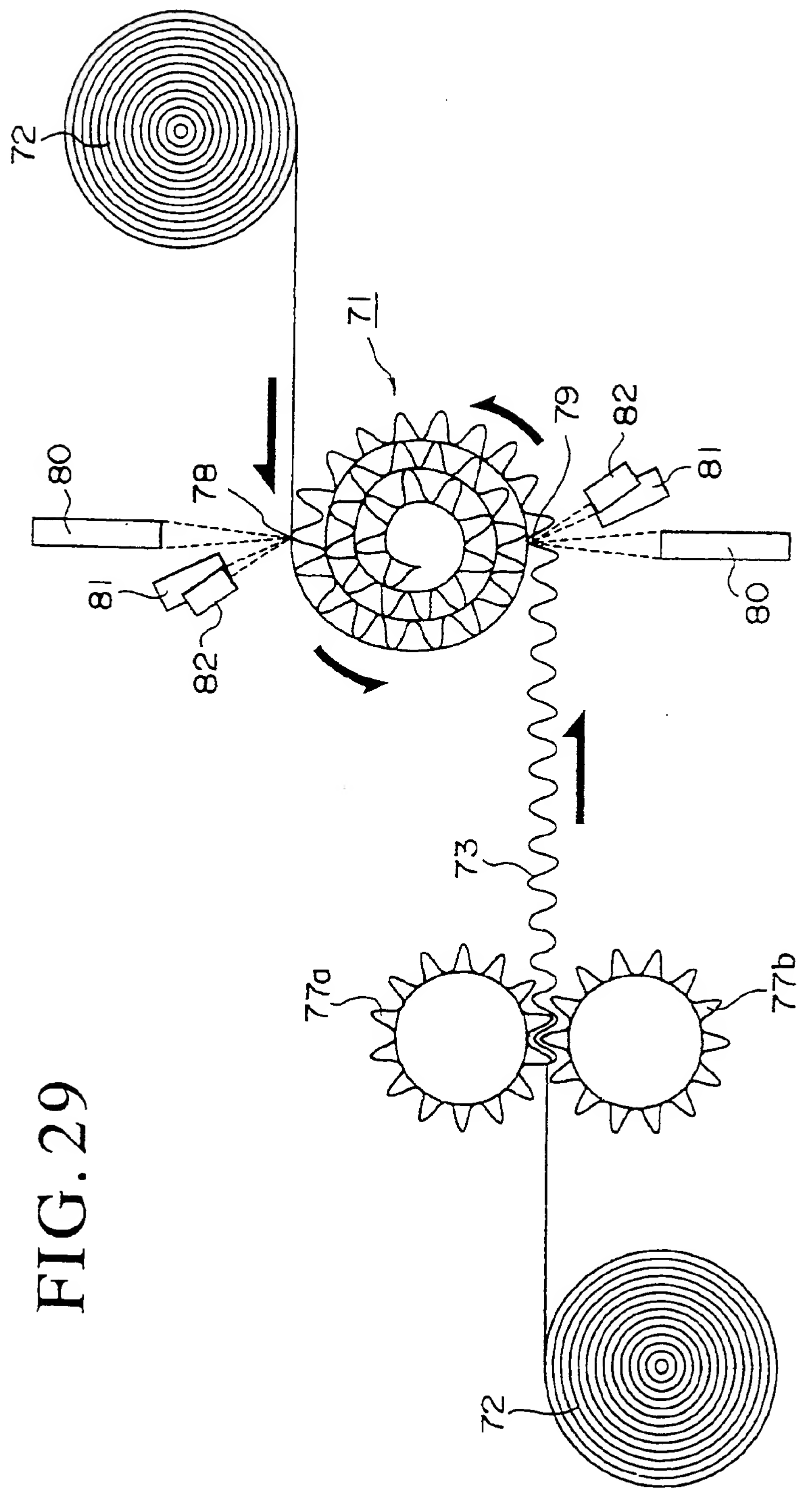


FIG. 29

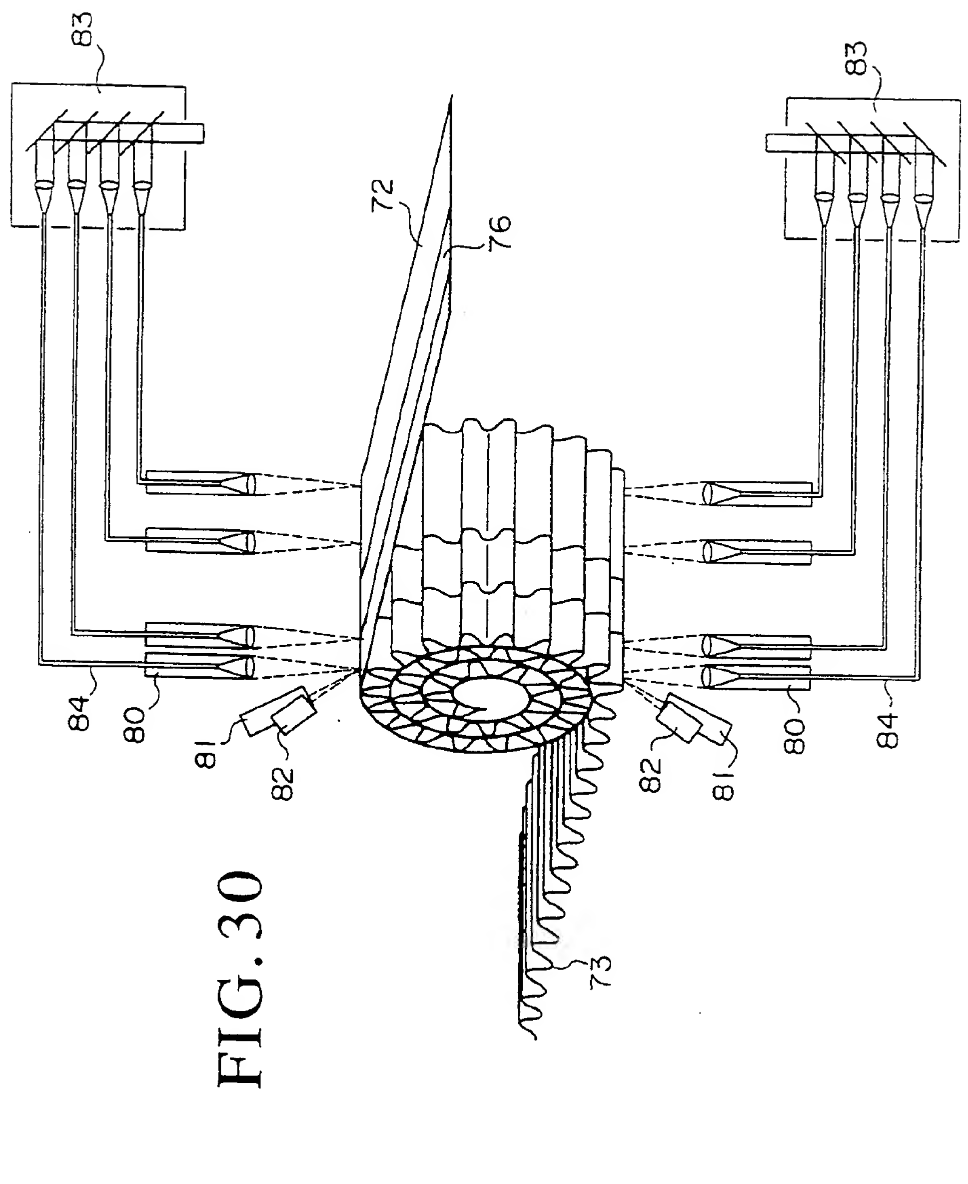


FIG. 30

FIG. 31

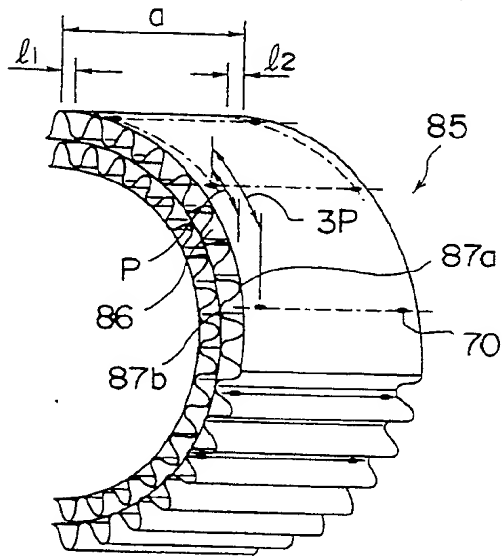


FIG. 32

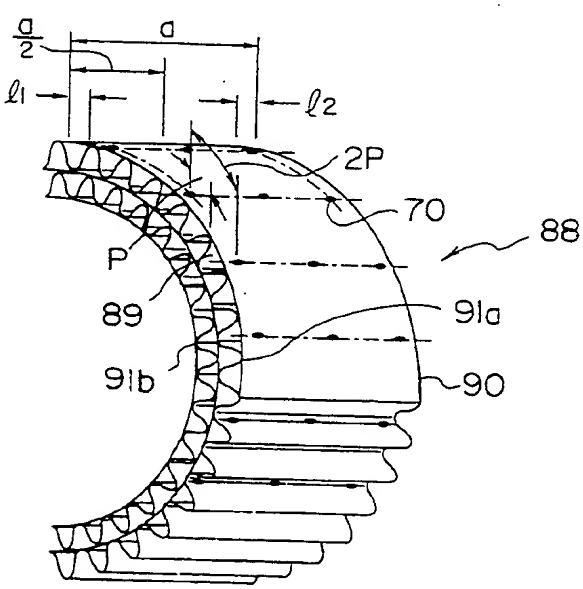


FIG. 33

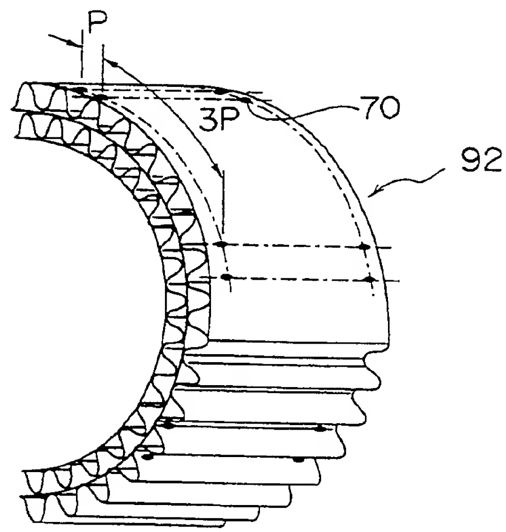


FIG. 34

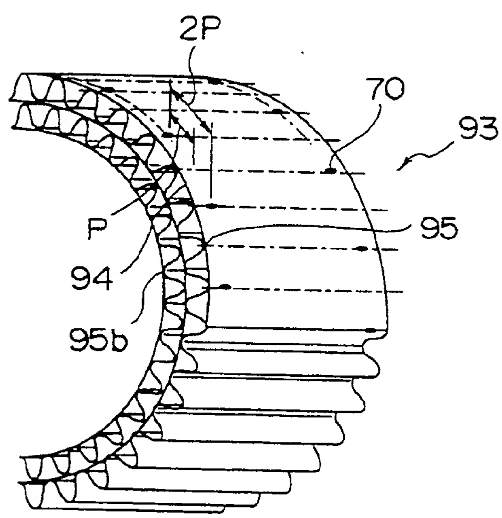


FIG. 35

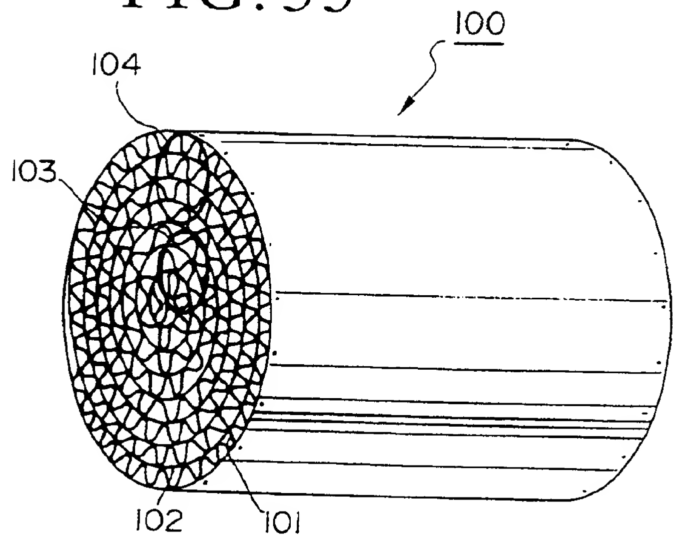


FIG. 36A

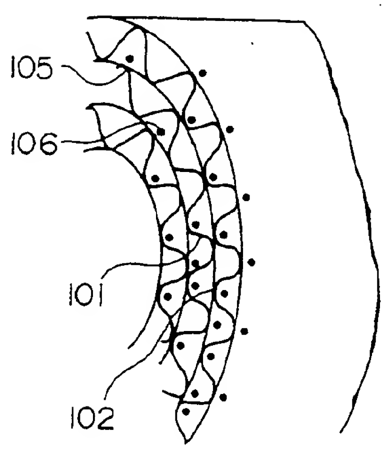


FIG. 36B

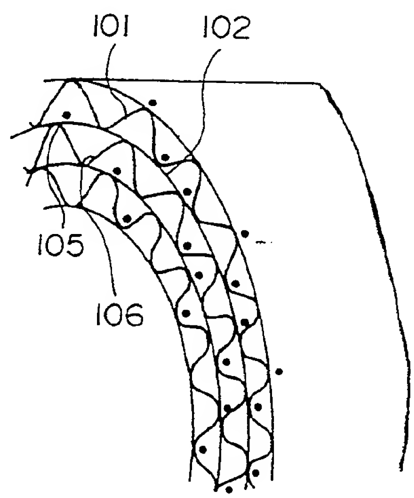


FIG. 37

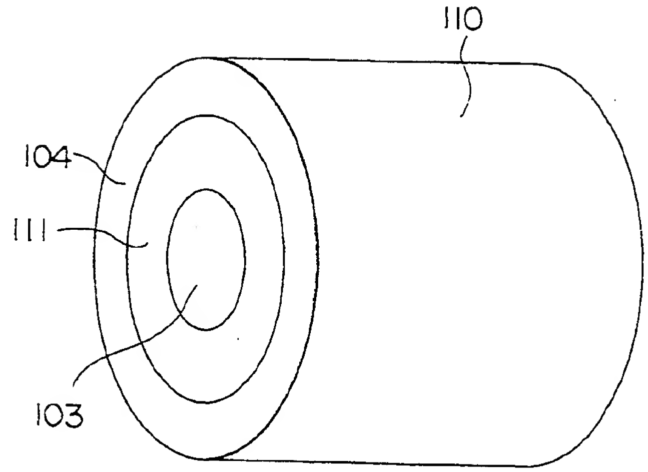


FIG. 38

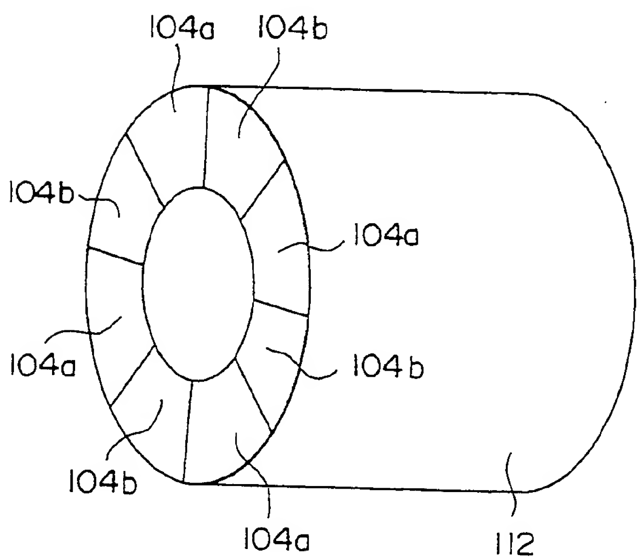


FIG. 39

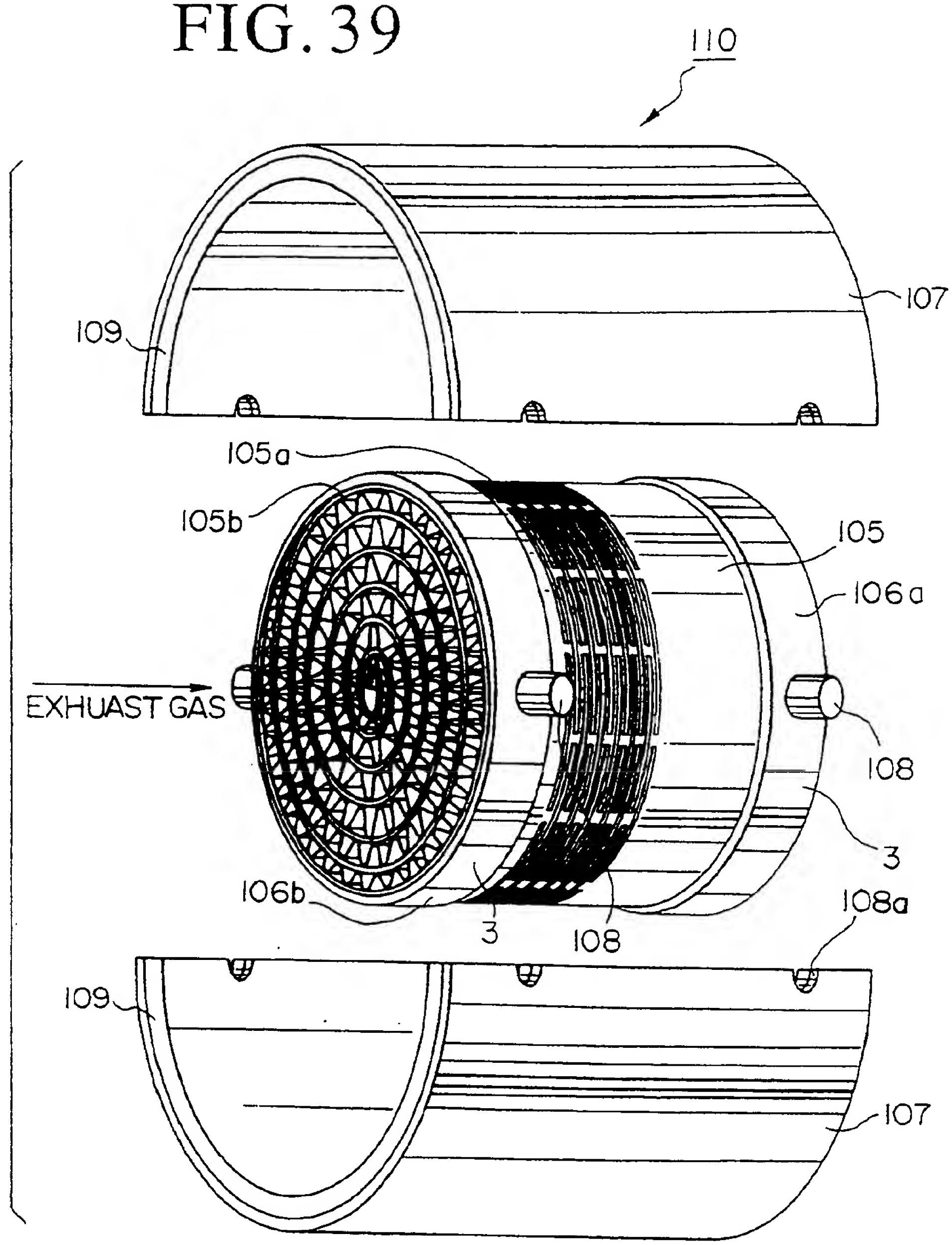

110
107
109
105a
105b
105
106a
EXHUAST GAS
108
3
106b
3
108
108a
109
107

FIG. 40

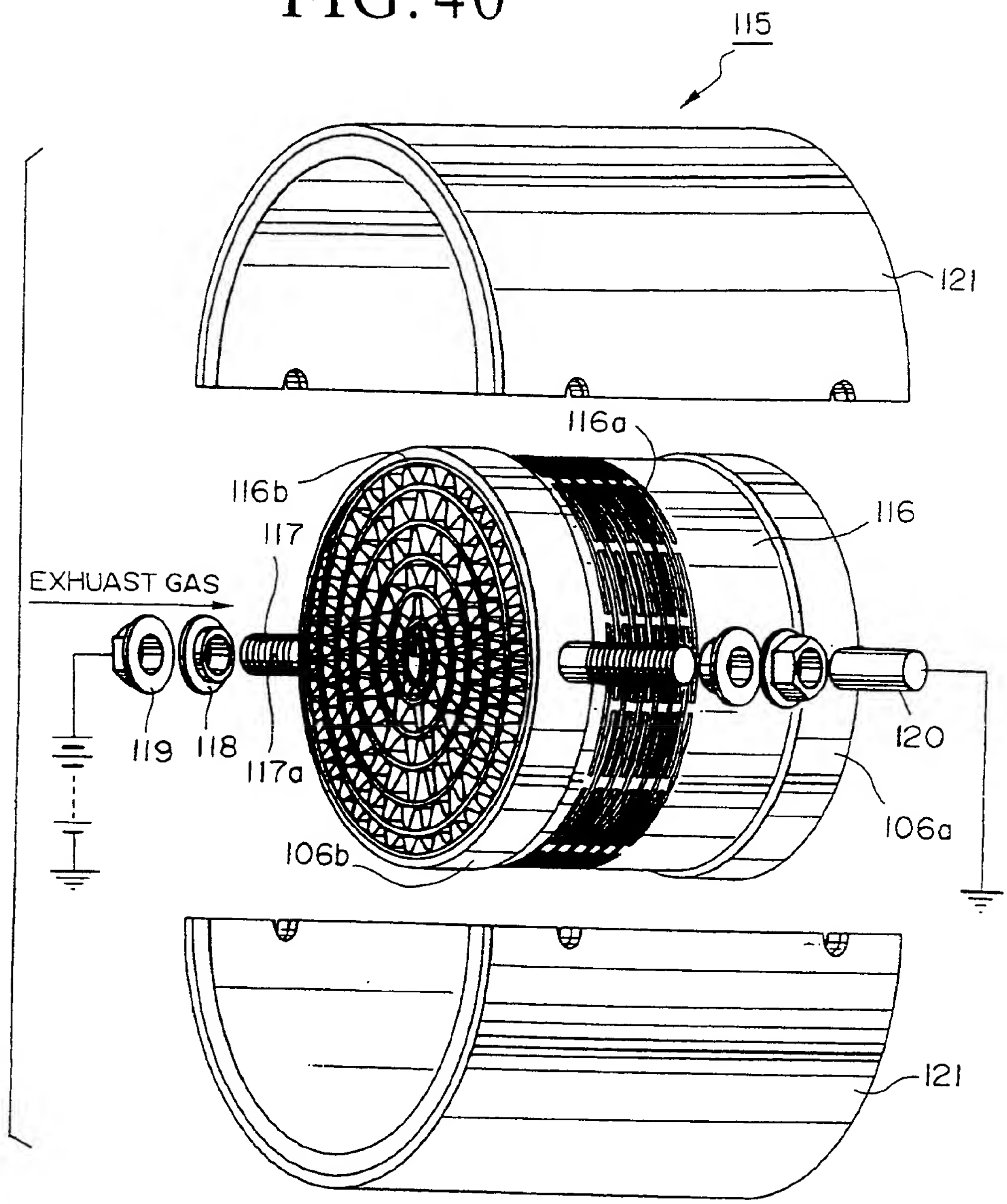

115
121
116a
116b
116
117
EXHUAST GAS
119
118
117a
120
106a
106b
121

FIG. 41

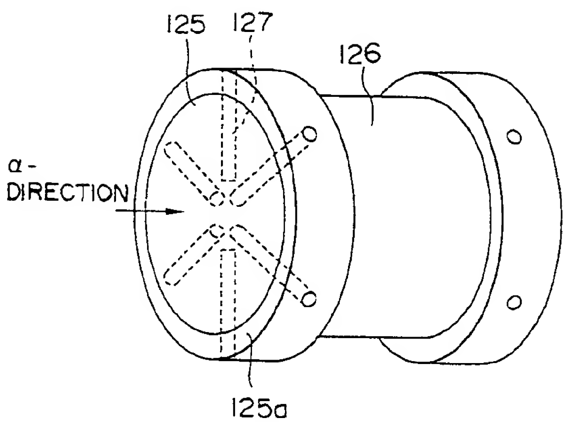


FIG. 42

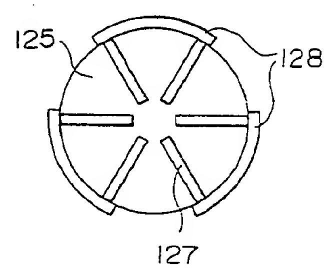


FIG. 43

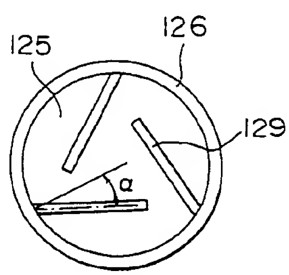


FIG. 44

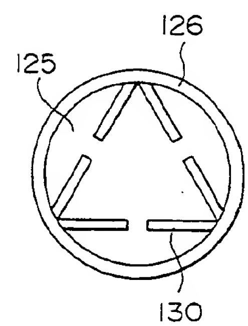


FIG. 45

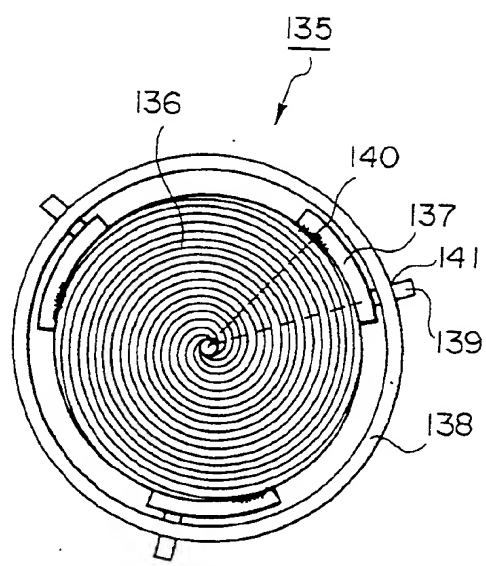


FIG. 46

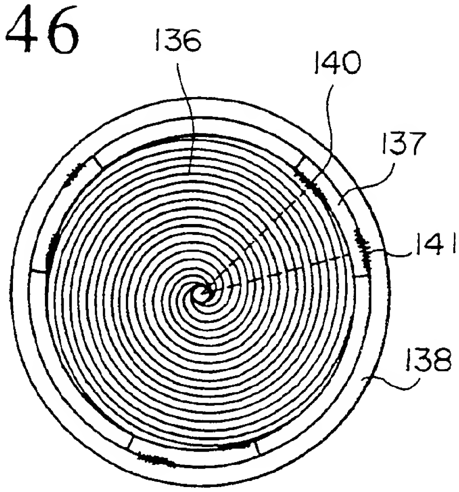


FIG. 52

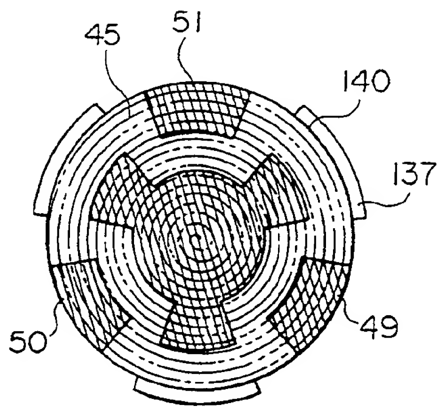


FIG. 49

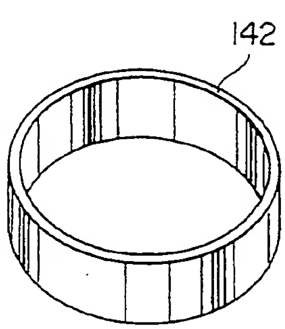


FIG. 50

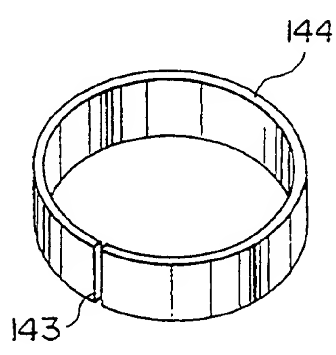


FIG. 47

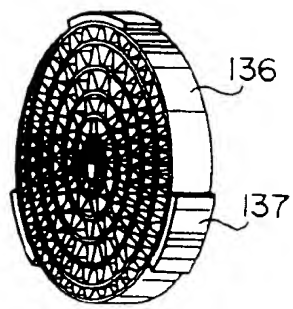


FIG. 48

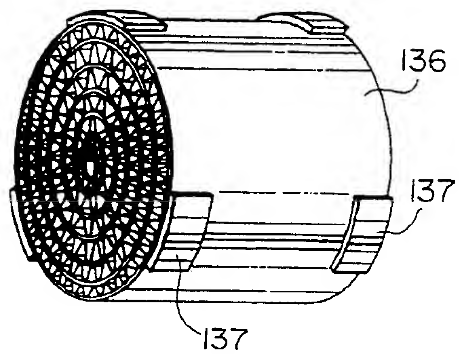


FIG. 51

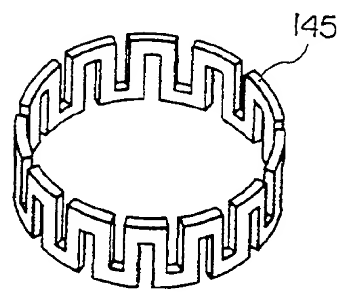


FIG. 53

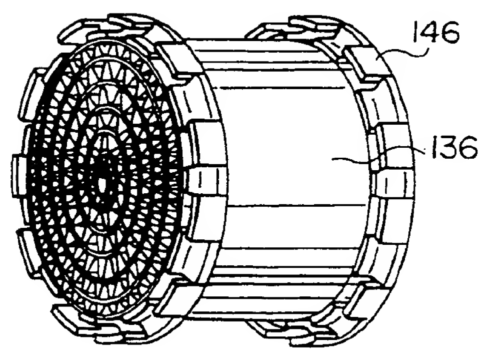
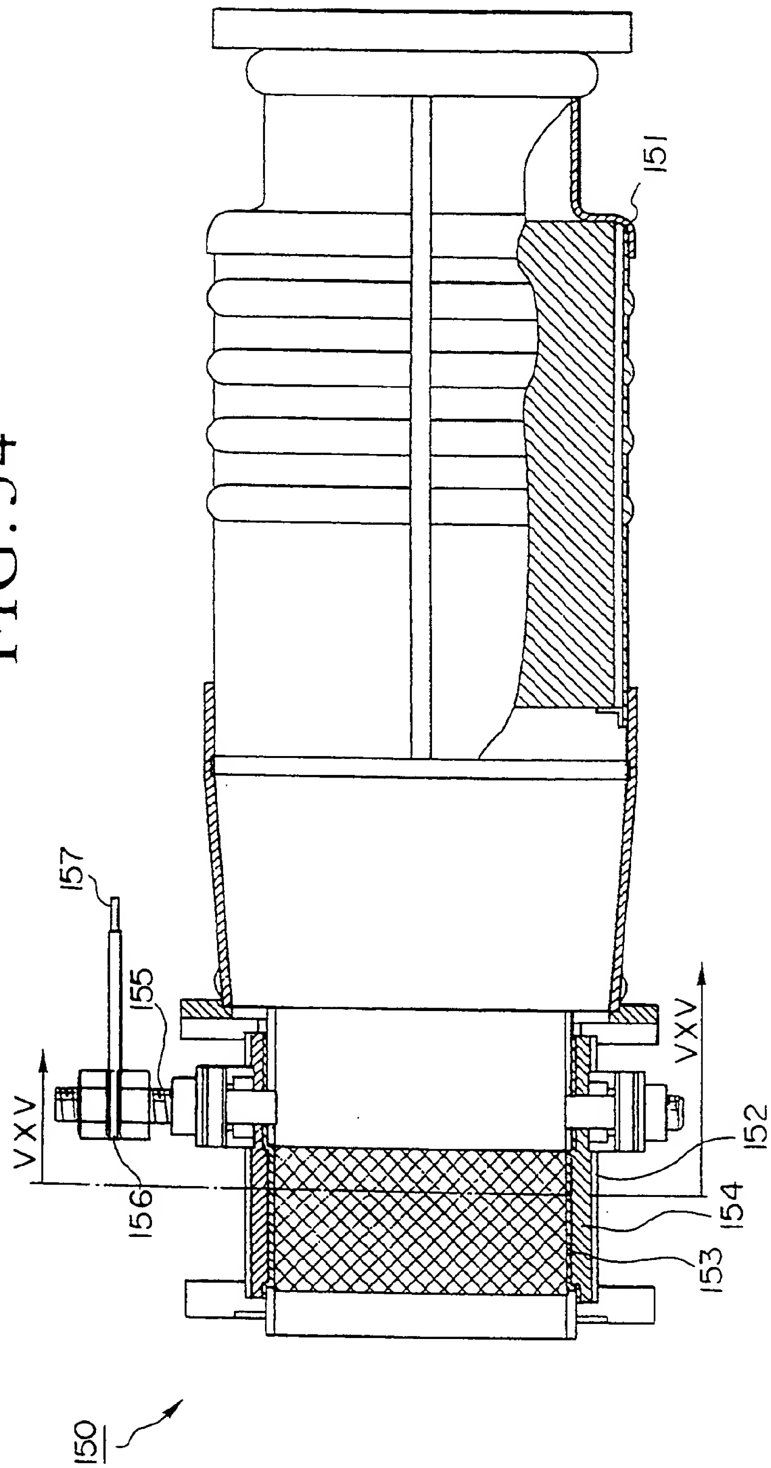


FIG. 54



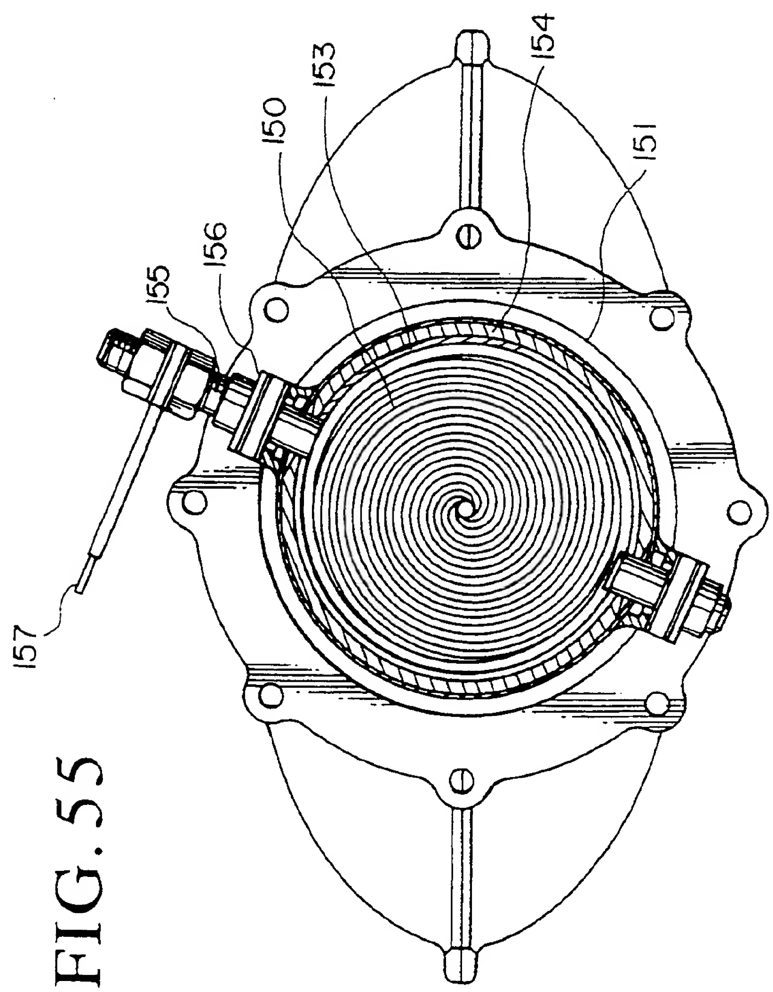
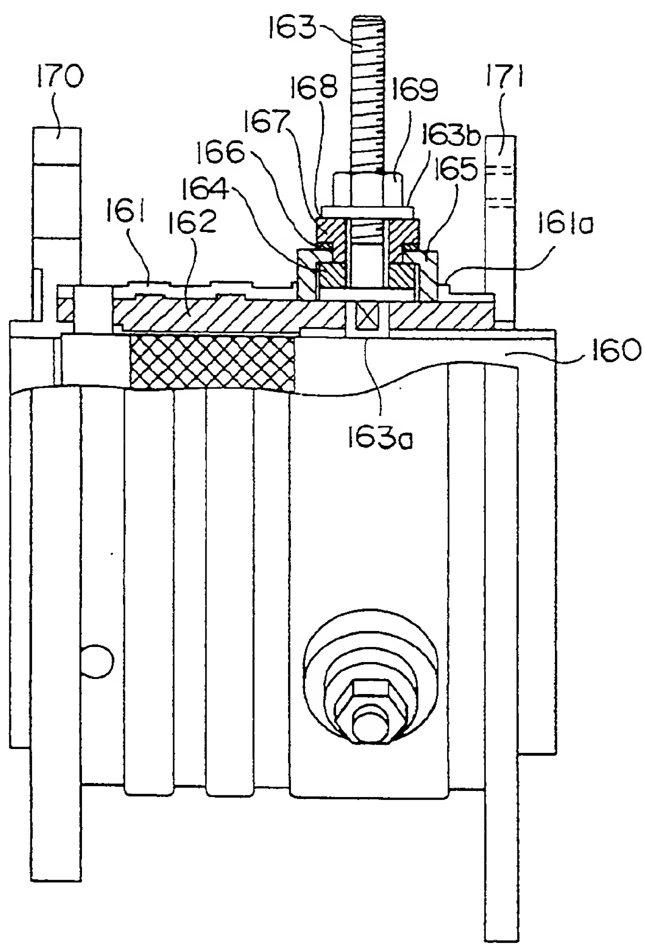


FIG. 55

FIG. 56



SELF-HEAT GENERATION TYPE HONEYCOMB FILTER AND ITS APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a self-heat generation type honeycomb filter and its apparatus, and more specifically, to a honeycomb filter employed for the catalytic converter of an automobile in order to accelerate the activation of substance bringing about a catalytic action.

2. Description of the Prior Art

Conventionally, conversion from noxious elements such as CO, HC, and NOx, included in exhaust gas, to innoxious gas or water, has been performed, for example, through a catalytic converter provided in an exhaust pipe line from an engine for an automobile. However, there has been a problem which can not be solved simply by the use of the converter, that is, a catalytic substance is not substantially activated in a state that the temperature of exhaust gas from an engine just after it start up, is too low to purify the exhaust gas substantially.

Consequently, it has been proposed in the U.S. Pat. No. 3,770,389 and Japanese Patent Unexamined Publication No. 2-223622 that a catalytic converter comprising a self-heat generation type honeycomb carrier including a separate self-heat generation type honeycomb filter into which catalytic substance is supported, is provided to a honeycomb carrier into which the catalytic substance of a catalytic converter is supported, so that when an electric current is applied to the self-heat generation honeycomb carrier and it heats up, then the activation of the catalytic substance is accelerated.

This self-heat generation type honeycomb carrier is formed of a corrugated metal plate shaped in belt having a wave-like irregular surface successively bent and a plane metal plate shaped in belt having a flat surface, the corrugated and plane metal plates are put on another, and rolled together or laminated in layer.

A self-heat generation honeycomb carrier has been also proposed in that an electric current is applied from the center of a catalytic converter toward outer side face through electrodes provided at the center part and outer circumferential face to heat up the converter.

However, when such self-heat generation type honeycomb carrier is employed, a predetermined value of resistance is required for the corrugated and plane plates in order to electrically heat them up and raise the temperature. Consequently, when the carrier into which an electric current is applied from the central electrode toward the outer side face, is employed, a belt-like material for the corrugated and plane plates requires a substantial length for each to ensure the value of resistance.

On the other hand, such conventional honeycomb carrier having a sufficient metal foil portion in length, as mentioned above, increases itself in thermal capacity. Thus, another problem to be solved is created; a preferable high performance in purification can not be obtained unless sufficiently great electric current in magnitude is applied to the carrier, since an increase in temperature is relatively slow when an electric current is applied.

It is preferred that both catalytic parts of the corrugated and plane plates are mechanically joined, in order to provide a sufficient strength in structure against vibration from an engine. However, it is extremely difficult to join them, while the electric insulation between them is completely ensured. Especially, when an electric current is applied from the central electrode toward the outer side face, both end faces welded to join each other can not have a sufficient resistance. Further, the end faces of the honeycomb carrier can not be simply welded, so that it is very difficult to keep the electric insulation, while the sufficient strength is ensured.

It takes a long time to heat up the catalytic substance up to the activation temperature with the conventional catalytic converter, since, when the converter is electrically heated up, the heat raised by thermal conduction in the metal foil forming the corrugated and plane plates is diffused into the whole carrier.

As described above, it is extremely difficult to realize both requirements for the converter simultaneously; a preferred value in resistance and a decrease in thermal capacity.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide a self-heat generation type honeycomb filter which has both high resistance and low thermal capacity, and also has low thermal conduction and durability, so as to raise the temperature up to the sufficient value with less power consumption.

In order to achieve the object, preferably the present invention provides a self-heat generation type honeycomb filer located in the exhaust pipe line system of an engine and formed of a plane plate and a corrugated plate, the filter comprising slit parts having openings at at least one part of said plane plate or corrugated plate.

According to the present invention, the provision of the slit parts facilitates to obtain a plane plate or a corrugated plate having a relatively high electric resistance compared with the conventional one.

Consequently, it is possible to raise the temperature with relatively low thermal capacity and less electric power, and short time, since there is no need to use long materials for the plane and corrugated plates as used to be.

The slit parts provided at the plane or corrugated plate allow a reduction in heat conduction extremely in the axial direction. The raised heat is regenerated in the catalytic converter to hasten the increase in temperature. Accordingly, the applied power can be save by the regeneration effect.

According to the present invention, it is possible to provide a self,heat generation type honeycomb filter which is very durable and capable of a high performance in purification with less power consumption.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a type schematic view of a catalytic carrier used for a self-heat generation type honeycomb filter according to the first embodiment of the present invention;

FIG. 2 is an exploded view showing a plane plate according to the same first embodiment;

FIG. 3 is a schematic view showing a connected condition of plane and corrugated plates of the catalytic carrier according to the same first embodiment;

FIG. 4 is a schematic view of a self-heat generation type catalytic converter located in a exhaust pipe line in association with the same first embodiment;

FIG. 5 is a cross sectional view taken along the line V–V' of FIG. 4;

FIG. 6 is an equivalent circuit view showing an equivalent circuit as a register of the carrier associated with the first embodiment of the present invention;

FIG. 7 is a schematic view showing another embodiment of a catalytic carrier of the self-heat generation type honeycomb filter according to the present invention;

FIG. 8 is a schematic view showing another embodiment of a joining condition of plane and corrugated plates of the catalytic carrier according to the present invention;

FIG. 9 is an illustration showing another embodiment of a slit shape on the plane or corrugated plate associated with the first embodiment of the present invention;

FIG. 10 is an illustration showing still another embodiment of a slit shape on the plane or corrugated plate associated with the same first embodiment;

FIG. 11 is an illustration showing still another embodiment of a slit shape on the plane or corrugated plate associated with the same first embodiment;

FIG. 12 is an illustration showing still another embodiment of a slit shape on the plane or corrugated plate associated with the same first embodiment;

FIG. 13 shows a schematic view of a catalytic: carrier used for a self-heat generation type honeycomb filter associated with the second embodiment of the present invention;

FIG. 14 is an exploded view of a plane plate of the catalytic carrier associated with the same second embodiment;

FIG. 15 is an illustration showing an embodiment of a slit shape on the plane or corrugated plate associated with the same second embodiment;

FIG. 16 is an illustration showing another embodiment of a slit shape on the plane or corrugated plate associated with the same second embodiment;

FIG. 17 is a schematic view of a catalytic carrier used for a self-heat generation type honeycomb filter associated with the third embodiment of the present invention;

FIG. 18 shows an illustration showing an embodiment of a slit shape on the plane or corrugated plate associated with the same third embodiment;

FIG. 19 is a schematic view of a catalytic carrier used for a self-heat generation type honeycomb filter associated with the fourth embodiment of the present invention;

FIG. 20 is an exploded view showing a plane plate of the catalytic carrier associated with the same fourth embodiment;

FIG. 21 is a schematic view showing a joining condition of the plane and corrugated plates associated with the same fourth embodiment;

FIG. 22 is a front view showing a joining condition of the plane and corrugated plates associated with the same fourth embodiment;

FIG. 23 is a front view showing another joining condition of the plane and corrugated plates associated with the same fourth embodiment;

FIG. 24 is a front view showing still another joining condition of the plane and corrugated plates associated with the same fourth embodiment;

FIG. 25 is an exploded view of the plane and corrugated plates of the catalytic carrier associated with the fifth embodiment of the present invention;;

FIG. 26 is an illustration showing a catalytic carrier associated with the sixth embodiment of the present invention;

FIG. 27 is an illustration showing a catalytic carrier associated with the seventh embodiment of the present invention;

FIG. 28 is an exploded view showing the plane plate of the catalytic carrier associated with the same seventh embodiment;

FIG. 29 is a schematic view of an apparatus for making the catalytic carrier associated with the same seventh embodiment;

FIG. 30 is a schematic view of the main part of the apparatus for making the catalytic carrier associated with the same seventh embodiment;

FIG. 31 is a schematic view showing a connected condition of the plane and corrugated plates of the catalytic carrier associated with the eighth embodiment of the invention;

FIG. 32 is a schematic view showing another connected condition of the plane and corrugated plates associated with the same eighth embodiment;

FIG. 33 is a schematic view showing still another connected condition of the plane and corrugated plates associated with the same eighth embodiment;

FIG. 34 is a schematic view showing still another connected condition of the plane and corrugated plates associated with the same eighth embodiment;

FIG. 35 is an illustration of a catalytic carrier associated with the ninth embodiment of the invention;

FIGS. 36A and 36B are type schematic views showing the connected conditions of the carrier associated with the same ninth embodiment;

FIG. 37 is a schematic view of a catalytic carrier associated with the tenth embodiment of the invention;

FIG. 38 is a schematic view of a catalytic carrier associated with the eleventh embodiment of the invention;:

FIG. 39 is an exploded, perspective view of a catalytic converter utilizing a catalytic carrier associated with the thirteenth embodiment of the invention;

FIG. 40 is an exploded, perspective view of a catalytic converter utilizing a catalytic carrier associated with the fourteenth embodiment of the invention;

FIG. 41 is a schematic, perspective view showing a connected condition of a catalytic carrier and an outer sleeve associated with the fifteenth embodiment of the invention;

FIG. 42 is a schematic, perspective view showing another connected condition of a catalytic carrier and an outer sleeve associated with the same fifteenth embodiment;

FIG. 43 is a schematic, perspective view showing still another connected condition of a catalytic carrier and an outer sleeve associated with the same fifteenth embodiment;

FIG. 44 is a schematic, perspective view showing still another connected condition of a catalytic carrier and an outer sleeve associated with the same fifteenth embodiment;

FIG. 45 is a schematic, perspective view showing a connected condition of a catalytic carrier and an outer sleeve associated with the sixteenth embodiment of the invention;

FIG. 46 is a schematic, perspective view showing a connected condition of a catalytic carrier and an outer sleeve associated with the seventeenth embodiment of the invention;

FIG. 47 is a schematic, perspective view showing another connected condition of a catalytic carrier and an outer sleeve associated with the same seventeenth embodiment;

FIG. 48 is a schematic, perspective view showing still another connected condition of a catalytic carrier and an outer sleeve associated with the same seventeenth embodiment;

FIG. 49 is a perspective view showing a shape of a support member associated with the same seventeenth embodiment;

FIG. 50 is a perspective view showing another shape of a support member associated with the same seventeenth embodiment;

FIG. 51 is a perspective view showing still another shape of a support member associated with the same seventeenth embodiment;

FIG. 52 is a schematic, perspective view showing still another connected condition of a catalytic carrier and an outer sleeve associated with the same seventeenth embodiment;

FIG. 53 is a schematic, perspective view showing still another connected condition of a catalytic carrier and an outer sleeve associated with the same seventeenth embodiment;

FIG. 54 is a schematic view of a self-heat generation type catalytic converter located in an exhaust pipe line system in association with the eighteenth embodiment of the invention;

FIG. 55 is a cross sectional view taken along the line VXV—VXV of FIG. 54; and

FIG. 56 is a schematic view of a self-heat generation type catalytic carrier associated with the nineteenth embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

(The first embodiment)

The first embodiment according to the present invention will be now hereinafter described in detail.

FIG. 1 is a schematic view of a self-heat generation type honeycomb carrier having a self-heat generation type honeycomb filter according to the present invention and a catalytic substance supported thereon.

A self-heat generation type honeycomb carrier 1 according to the embodiment, has a configuration in that a plane plate 2 and corrugated plate 3 have slits formed at locations other than a down stream side end portion 1*a* into which an electric current flows, and an up-stream side end portion 1*b* of which the current flows out, and both plates are layered and rolled in spiral shape.

The carrier 1 has also a power supply 4 and a switch 5 provided at the side end portion 1*a* and the portion 1*b* is grounded, so that an electric current flows between the both portions 1*a* and 1*b*.

FIG. 2 is a front view showing the shape of the first slit portion 2*a* in detail, formed at a plane plate 2 employed in the first embodiment.

The first slit portion 2*a* according to the first embodiment is provided between an up-stream side end portion 1*b* with a width l_1 and the down-stream side end portion 1*a* with a width l_2. A plurality of openings 6 are formed therein to be arranged in that each opening shaped in diamond has a long diagonal line a and a short one b, and arranged in that positions of the openings 6 are shifted each other by a half the length a; a/2.

The plane plate 2 is composed of Fe-Cr-Al material containing Cr; 18–24 wt %, Al; 4.5–5.5 wt %, rare-earth metal (REM); 0.01–0.2 wt %, and Fe; all the rest, and shaped in belt having a thickness; t=0.03–0.05 mm.

The corrugated plate 3 has also the second slit portion 3*a* formed in the same shape as the first slit portion 2*a* formed at the plane plate 2, and further irregularities are formed successively thereat.

In FIG. 3, a method of producing a self-heat generation type converter according to the first embodiment will be described.

A self-heat generation type converter 1 according to the embodiment is produced in the following manner.

As shown in FIG. 3, the plane plate 2 and corrugated plate 3 are layered by means of semi-cylindrical winding tools 7*a* and 7*b*, so that the second slit portions 3*a* of the plate 3 and the first slit portions 2*a* of the plate 2 face each other. The winding tools 7*a* and 7*b* are rotated on its center to wind up the plates up to a predetermined dimension, and removed when the wound up plates reach to the predetermined dimension.

After winding up till they reach to the predetermined dimension, portions in contact with the plate 2 and 3 at both end faces, are electrically shorted by means of electric discharge welding, laser welding, or soldering to join the plate 2 with the plate 3.

This structure is heated up at temperatures of 800° C.–1200° C. for 1–10 hours to let Aluminum oxide deposit onto the metal surface, so that the full range of the contact portions between plates 2 and 3 are joined by the Aluminum oxide. The structure is processed in Wash-Coating, that is, it is impregnated into a slurry containing γ-Al_2O_3, and then baked.

After that, the structure is impregnated into an aqueous solution in which a catalytic metal, for example, Pt or Ph is dissolved, and sintered again.

As a result, a self-heat generation type honeycomb carrier 1 having γ-Al_2O_3 and catalytic substance adhered thereonto, is provided.

A casing for the above honeycomb carrier 1 will be described. The carrier 1 according to the first embodiment is mounted in the exhaust pipe line of an automobile by the casing.

In the first embodiment, the honeycomb carrier 1 has dimensions; 67 mm in diameter and 78 mm in length. The first slit 2*a* and second slit 3*a* of the plane plate 2 and corrugated plate 3 are the same in shape and each dimension of the portions referred in FIG. 3; l_1=10 mm, l_2=36.5 mm, l_3=31.5 mm, l_4=0.15 mm, l_5=6 mm, and l_6=2 mm.

Thus, a plane plate 2 is made of Fe-Cr-Al-REM and has a thickness of 0.05 mm and slits shaped therein in the dimension as mentioned above, and a corrugated plate 3 is made of the plane plate 2 which is processed into a corrugated plate material having a wave height of 1.875 mm, a wave pitch of 3.75 mm. Then both two plates 2 and 3 are layered together and wound in round shape.

FIG. 4 is a structural view showing this self-heat generation type honeycomb carrier 1 mounted in an exhaust pipe line.

As shown in FIG. 4, an up-stream side ring 8 and a down-stream side ring 9 each made of stainless steel are soldered at an up-stream side end portion 1*b* and a down-stream side end portion 1a, respectively. A flange 11 is welded with the up-stream side ring 8 so as to mount an exhaust manifold 10 thereto. A supporting bar 12 made of stainless-steel is mounted at the ring 8 as

shown in FIG. 5 showing a cross sectional view taken along the, line V—V in FIG. 4.

The bar **12** is air-tightly fixed with a ceramic gasket **14** and the first and second copper gaskets **15***a* and **15***b*, and a nut **16** to be screwed onto the thread portion of the bar **12**, so that the bar **12** is electrically insulated from an outer circumferential case **13**. A ceramic main monolith catalyst **19** having a volume of 1,300 cc, supported in a case **17** having a oval shape in cross section by a wire net **18**, is supported at the down-stream side just below the carrier **1**.

According to the first embodiment, when a slit shape shown in FIG. 2, is employed, the resistance of each foil portion $l_4 \times l_5$ left after the first and second slits 2*a* and 3*a* are taken away, has about 1Ω, therefore, the structure, as a whole, has an equivalent circuit shown in FIG. 6.

Namely, each register in FIG. 6 is about 1Ω, so that it is possible to provide a group of relatively high registers having resistances about 0.13Ω as a whole.

When operating power having an electric current of about 75–100 A at a voltage 10–20 V is supplied just after engine start-up to the self-heat generation type honeycomb carrier **1** having the structure as mentioned above, it takes about 20 seconds (the engine in idling state) to heat up the carrier **1** to the temperatures of 400° C.–500° C., and catalyst is activated to purify exhaust gas.

As described above, the carrier **1** according to the embodiment has a plane plate **2** and a corrugated plate **3** on which the first and second slits 2*a* and 3*a*, are provided, respectively, so that it is easy to provide a register having high resistance when an electric current is applied between the up-stream and down-stream side end portions 1*a*, 1*b*. Therefore, there is no need to use a long metal foil to ensure a sufficient resistance any longer as conventionally used to do, thus a structure having relatively low thermal capacity can be realized. Accordingly, the catalyst is heated up and activated for a short time with less power.

The first and second slits 2*a* and 3*a* formed in the plane and corrugate plates **2** and **3**, respectively, are shifted in the axial direction of the carrier **1**, such that the position of the slit interval is alternately shifted by the half of the length in the axial direction. Therefore, its heat conduction is extremely reduced in comparison with one of a conventional self-heat generation type honeycomb carrier having no slit.

For example, with a slit size used in FIG. 2, the ratio is about 8×10−4 times, so heat while an electric current is applied and the temperature is raised up, is easy to be regenerated in the carrier **1**. Accordingly, there are some portions which reach the activation temperature of catalyst faster after heating starts, then those portions produce the heat of catalytic reaction to activate the another portions. Thus, an applied power is saved by this regeneration effect.

The use of the first and second slits 2*a* and 3*a* formed at the plane and corrugate metal foil plates **2** and **3**, respectively, can reduce extremely its thermal conductivity, so that heat while an electric current is applied and the temperature is raised up, is easy to be regenerated in the carrier **1**. Accordingly, there are some parts which reach to the activation temperature of catalyst faster in comparison with one of a conventional carrier after heating starts, then the entire body is quickly raised in temperature and activated by the heat of catalytic reaction produced from those parts. Namely, an applied power is reduced by this regeneration effect.

The catalytic portions at both end faces of the corrugated and plane plates are completely welded, so that an extremely rigid and durable self-heat generation type honeycomb carrier which can endure against thermal load and engine vibration, is realized.

In the embodiment mentioned above, the cross sectional view is a round shape, though, it is not limited to this shape, for example, as shown in FIG. 7, a converter **20** may be formed by winding to be an oval shape (a track) in cross-sectional view.

As shown in FIG. 8, a converter having a cross sectional shape to be the same as the shape in FIG. 7 may be formed by laminating the corrugated and plane plate materials **1** and **2**, alternately.

The slit shape provided for the plane and corrugated plates **2** and **3**, made from Fe-Cr-REM, is a diamond shape in the first embodiment, though, it is also not limited to this, it may be a lattice shape either in FIGS. **9**, **10**, **11** or **12**.

Namely, a slit or opening **22** shaped as shown in FIG. 9, is easy to produce, since first of all, a material is processed to have breaks in the longitudinal direction by a shearing machine or the like, and then beaten out.

Slits or openings **22** and **23** shown in FIG. **9** and **10**, are also easy to produce by processing the material with etching and press machines or the like.

Plane and corrugated plates having a slit pattern **24** as shown in FIG. **11** may have a slit shape in another embodiment.

There is no need for the slit shape to be a single type, and each slit may be located variously depending on a certain area as shown in FIG. **11**, so that a register having high resistance is arranged at the front portion which is heated up easily by exhaust heat so as to efficiently utilize the less power consumption effect.

As shown in FIG. **12**, plane and corrugate plates having no slits formed on their down-stream and up-stream sides in an exhaust pipe line may be also possible.

It was described as an example that the carrier according to the invention as shown in FIGS. **4** and **5**, was fixed extremely adjacent to the exhaust manifold so as to quickly heat it up by the heat of exhaust gas. However, it should be noted that such location will be under the extremely severe environment caused by the high temperatures of exhaust gas and the vibration of an engine while an automobile is in operation.

This carrier **1** is extremely rigid and durable enough without problem for thermal load and engine vibration, since the corrugated and plane plates at both end faces are mechanically joined in welding, and all range of plates are joined with Aluminium oxide by means of oxidizing heat treatment.

Slits are provided at the plane and corrugated plates forming a self-heat generation type honeycomb carrier which is a self-heat generation type honeycomb filter with catalyst supported thereon in the first embodiment. However, a self-heat generation type honeycomb filter which is capable of generating sufficient heat as in the embodiment, is provided, even when slits are provided at plane and corrugated plates forming a self-heat generation type honeycomb filter without catalyst supported thereon, and the filter is small.

(The second embodiment)

FIG. **13** shows a structure according to the second embodiment.

In this second embodiment, there is provided a slit shape which is suitable for raising temperatures quickly.

The second embodiment will be described hereinafter in detail.

A honeycomb carrier **30** is a honeycomb body formed of a plane plate **31** and a corrugated plate **32** having slits formed successively thereat, respectively.

FIG. **13** is an exploded view of the plane plate **31**, and corrugated plate **32** made of the plane plate **31** which is processed by bending to form wave-like irregularities successively in the longitudinal direction, forming the honeycomb carrier **30**.

As shown in FIG. **14**, the plane and corrugated plates **31**, **32** according to the embodiment, have end portions **30***a* and **30***b* without slit thereat, having widths l_1 and l_2, respectively, left at both edges of a thin plane material made of stainless steel (ex. Fe-20Cr-5Al). The plates **31**, **32** have also arbitrary shaped small holes or slits **31***a* formed successively at the middle portion 13.

At least either one of the horizontal width b or vertical width a of an opening **33** forming the slit **31***a* is shrunk at the boundary portions **17**, **18** between the end portions **30***a*, **30***b* and the central portion **19**. Therefore, either one of the slit width l_4 or interval between openings l_6 at the boundary portions l_7, l_8, is expanded.

On the other hand, it is characterized in that the slit width l_4 and interval between openings l_6 at the rest except opening **33** at the central portion **19**, are shrunk in this embodiment.

The slits in FIG. **14** are easily produced, since holes shaped in parallelogram are just simply formed successively.

A method of producing a honeycomb carrier **30** according to the second embodiment will be hereinafter described.

A honeycomb carrier **30** in FIG. **13** is formed in such a manner that at least one pair of the plane and the corrugated plates **31** and **32** is layered together and wound in cylindrical shape. The honeycomb carrier **30** formed in this way, is joined by means of laser welding, electric discharge welding, or soldering on its both end faces, so that all the contact portions between the plane and corrugated plates **31** and **32** layered together are joined at the ranges having width l_1, l_2 to be electrically shorted.

Electrodes (not shown) for applying electric power are provided at these portions l_1, l_2, each electrode is connected either to the controller **34** of a power source **4** or the ground.

Operation in the second embodiment will be hereinafter described.

An engine mounted at the up-stream side, is started up after the honeycomb carrier **30** according to the second embodiment is assembled as per the first embodiment in FIG. **4**.

Unpurified gas is exhausted just after the start up, since temperatures of catalyst is still low. In this embodiment, an electric current is applied to the carrier **30** just before, at the same time, or just after the start up. The current flows from the end face to the end face of the carrier **30** along the flowing direction of the exhaust gas, and generates heat preferentially at its middle portion l_3, because slits are formed there to be high resistance. An increase in temperature is fast due to low thermal capacity and it reaches to the activation temperature of catalyst at a short time. Once it reaches to the preferred temperature, the heat is not easy to radiate to the adjacent exhaust pipe, housing due to the low thermal conductivity. Therefore, high regeneration effect is ensured.

However, the heat generation is preferentially produced at the middle portion 13, but not much at the portions having widths l_1, l_2, so that thermal stresses are concentrically created at the boundaries **17**, **18**.

The openings **33** at these boundaries l_7, l_8 are formed in a compact size in the second embodiment, so as to extend both of the remaining slit width l_4 and interval between openings l_6, respectively. Accordingly, the heat generation at the boundaries l_7, l_8 is an intermediate degree between the heat generations at the middle portion l_3 and portions having widths l_1, l_2.

Consequently, heat stress caused by a difference in heat generation between the portions of widths l_1, l_2, and the middle portion l_3, are relieved. According to the second embodiment, the honeycomb carrier **30** allows an improvement in durability against heat stress.

It also contributes to the effect mentioned above that a mild temperature gradient is provided with an intermediate value in electric resistance at the boundary portions l_7, l_8, and less heat generation at the portions than at the central portion l_9.

Consequently, the purification efficiency for exhaust gas is improved by quick activation, while the high durability is ensured.

Though the slit has a diamond shape in the second embodiment, it is not limited to this shape. It may be a rectangular slit **15** as shown in FIG. **15**, a bent-up line shaped slit **36** as shown in FIG. **16**, or a curved slit.

Anyone of these slits can control its resistance value by a change in its width and interval between slits. However, the slits shown in FIG. **16** are more suitable than the other for obtaining high resistance.

These slits mentioned above are produced in arbitrary ways, such as etching, laser cutting, stamping by press machine, for example, a material is cut by cutting roller and then drawn or beaten to extend. Thus various other ways may be considered.

The honeycomb carrier **30** in the second embodiment, is produced in a manner that the plane and corrugate plates **31** and **32** are alternately layered and then wound to be a round honeycomb in a cross section, though, the present embodiment is not limited to this. The cross sectional shape can be freely selected depending on situation such as mounted positions.

The electrodes through which power is applied to the carrier **30**, may have an arbitrary shape as far as a flow of exhaust gas is not prevented thereby, and it is considered other than bar-like electrodes that they may be a ring shape having widths l_1, l_2, respectively, to be fixed onto the cylindrical side face of the carrier **30**. It may be also possible to employ bolt-shaped electrodes, so as to function in both ways as an electrode and a device to fix the carrier **30** on the housing.

When a honeycomb carrier **30** according to the second embodiment is employed instead of the self-heat generation type honeycomb carrier **1** as shown in FIG. **4**, a heat insulator made of an inorganic fiber may be put into the gap between the housing (not shown) and carrier **30**. This structure allows an improvement in heat insulating effect and electric insulation between the carrier **30** and housing, and further it supports the carrier **30** with its whole side face to improve the resistance against vibration.

When a thermal expansionable material (vermiculite) or the like is mixed with it, the supporting capability for the carrier is much more improved.

The honeycomb carrier 30 mentioned above, has γ-Al_2O_3 Wash-coated and catalyst supported thereon, so it has a function of purification itself. However, it may be also considered that this structure is made in a small volume of 100–200 cc as a sub-catalyst, and this is used in combination with a main catalyst made in a large volume and of metal or ceramic monolith. In this case, the main and sub-catalysts are arbitrary located. A structure in which a plurality of these catalysts are combined, may be employed for a large displacement engine.

(The third embodiment)

The third embodiment relates to a region at which a catalyst is supported on a self-heat generation type honeycomb carrier.

FIG. 17 shows a honeycomb carrier 40 according to the embodiment, in which like reference characters denote like parts.

The honeycomb carrier 40 is formed in the same shape as the honeycomb carrier 1 shown in FIG. 1, and connected to a power supply 4 and a controller 34. An electric current is applied to the carrier 40 from the up-stream to down-stream or vice-versa along a flow of exhaust gas.

The region A in a range of a certain width 13 from the up-stream side end face, has not γ-Al_2O_3 Wash-coated and catalyst supported thereon in the third embodiment. This structure allows a reduction in thermal capacity for the carrier 40.

Operation in the third embodiment will be hereinafter described.

An engine mounted at the up-stream side (not shown), is started up after the honeycomb carrier 40 according to the embodiment is assembled as shown in FIG. 4.

When the main monolith 19 is activated just after the start up, an electric current is applied to the honeycomb carrier 40 to activate the catalyst supported in the honeycomb carrier 40.

This carrier 40 has porosity, so that high resistance and low thermal capacity are realized to raise the temperature of the carrier smoothly, though, the region A can reach to the activation temperature much faster, because the region A on which no catalyst is supported thereon, has lower thermal capacity.

Heat in the region A is conducted to the down-stream by thermal conduction and a flow of exhaust gas, to accelerate the increase in temperature and activation rapidly. The activation of catalyst is rapidly accelerated, so that the unpurified exhaust gas is extremely reduced in quantity.

A slit employed in the third embodiment may be a shape of a slit 41 shown in FIG. 18, other than shapes shown in FIG. 9, 10, 11, and 12 of the first embodiment.

(The fourth embodiment)

In the fourth embodiment, it is characterized that a part at which a plane plate and a corrugated plate are not joined together, is provided in the most outer circumferential region.

The fourth embodiment will be hereinafter described in detail.

FIG. 19 is a partial cross sectional view of a catalytic converter according to the fourth embodiment.

A honeycomb carrier 45 is formed of a plane plate 46 and a corrugated plate 47. The first slits 46a are formed at the plane plate 46 as shown in FIG. 20, and the second slits 47a at the corrugated plate 47 as shown in FIG. 22.

The corrugated plate 47 has also the second slit part 47a formed in the same shape as the first slit part 46a formed at the plane plate 46.

The first and second slits 46a, 47a are provided between the down-stream side end portion 45a and up-stream side end portion 45b having widths l_1, l_2, respectively. A plurality of the first slits 46a are arranged in that each slit shaped in diamond has a horizontal length a and a vertical length b, and the position of the length a is shifted each other by a half of the length a; a/2.

In the fourth embodiment, the plane and corrugated plates 46a and 47a have the following dimensions: l_1=10 mm, l_2=43 mm, l_3=25 mm, l_4=0.4 mm, l_5=45 mm, l_6=5 mm, and b=0.4 mm.

A plane plate 46 is made of Fe-Cr-Al and has a thickness of 0.05 mm and a corrugated plate 47 is made of the plane plate 46 which is processed into a corrugated plate material having a wave height of 1.9 mm, a wave pitch of 3.75 mm. Then both two plates 46 and 47 are layered together and configured in round shape.

As shown in FIG. 21, the plane and corrugated plates 46a and 47a are layered by means of semi-cylindrical winding tools 48a and 48b, so that the second slit parts 47a of the plate 47 and the first slit parts 46a of the plate 46 face each other. The tools 48a and 48b are rotated on its center to wind up the plates up to a predetermined dimension, and removed when the wound up plates reach to the required dimension.

The plane and corrugated plates 46, 47 are composed of Fe-Cr-Al material containing Cr; 18–24 wt %, Al; 4.5–5.5 wt %, rare-earth metal (REM); 0.01–0.2 wt %, and Fe; the rest of all, and shaped in belt having a thickness; t=0.03–0.05 mm.

After winding up, the honeycomb body wound by metal foil composed of the material mentioned above, is joined in a pattern as shown in FIG. 22. Then, it is heated up at the temperatures of 800° C.–1200° C. for 1–10 hours and processed in Wash-Coating, that is, it is impregnated into a slurry containing γ-Al_2O_3, and then baked. After that, it is impregnated into an aqueous solution in which a catalytic metal, for example, Pt or Ph is dissolved, and sintered again. As a result, a catalytic honeycomb carrier having γ-Al_2O_3 and catalytic substance adhered thereonto, is obtained.

Rings 54a, 54b are joined onto the honeycomb carrier 45 by means of laser welding or soldering as shown in FIG. 19. A catalytic converter 60 according to the fourth embodiment is provided by casing the carrier 45 with an electrode 55, an outer cylinder 56, flanges 57a and 57b. The converter 60 is mounted in the exhaust pipe line of an automobile.

The converter 60 is configured such that an electric current is applied to the honeycomb carrier in the axial direction to electrically heat it up by force, and activate catalyst and then purify noxious exhaust gas under idling condition just after an engine starts up.

Features according to the fourth embodiment will be hereinafter described.

It is characterized how the plane and corrugated plates 46 and 47 are joined after wound in round shape, and it will be described hereinafter with reference to FIG. 22.

Namely, FIG. 22 shows joined ranges on the end face 45a of the self-heat generation type catalytic converter 45.

Referring to FIG. 22, there are the first region 49, second region 50, third region 51, each being selectively

joined by means of soldering, laser welding, electric discharge welding or the like, adjacent to the outer circumferential part shown by slant lines on the end face **45a** of the honeycomb carrier **45**, and the forth region **52** is also a joined part formed in the same manner on the central part.

As shown in FIG. **22**, each of the first region **49**, second region **50**, and the third region **51**, is selectively joined adjacent to the outer circumferential portion, and is joined only for a part of the length in both radial and circumferential directions.

On the other hand, at the central portion, the fourth region **52** is completely joined within a circular region which is almost equivalent to the half of a radius of the honeycomb body.

Namely, the welded ranges are, as a whole, orderly arranged from the center of the carrier **45** to the radial direction.

Each of the first region **49**, second region **50**, and third region **51** provided adjacent to the outer circumference, is joined to have overlapped regions **53**, each of which is overlapped with at least one cell located within the circumference of the same radius as of the projections of the fourth region **52** provided at the center portion, facing other regions with non welded portions therebetween.

In the fourth embodiment, the following effects are provided with these regions joined in the way mentioned above.

Namely, when a catalytic converter **45** according to the embodiment is fixed in the exhaust pipe line of an automobile, thermal stress is produced during a heat-cycle process caused by rapid heating and cooling at the center portion of the honeycomb carrier when an engine start up and engine brake is applied, respectively. However, these thermal stress produced during the heat-cycle process is relieved by the converter **45** in which the non joined portion of the plane and corrugated plates **46, 47**, which are provided adjacent to the outer circumference, are freely deformed in the radial and circumferential direction.

The thermal stress is produced by differences in the linear expansion coefficient, thermal capacity, and radiation area between the honeycomb carrier **45** and outer cylinder **56**, rings **54a** and **54b** in FIG. **19**.

This thermal stress is at a maximum adjacent to the outermost circumference where the difference in temperature distribution in the radial direction of the carrier **45** is also at a maximum. When a non-joined portion as in the fourth embodiment, is provided at a position where the maximum thermal stress is produced, it is efficiently relieved.

Namely, the smaller the joined area is, the greater the thermal stress is relieved, though it is weaker against vibration. That is, the greater the area is, the better the durability is. The selective joining method according to the present invention overcomes this contradictory problem.

Welded ranges are orderly arranged from the center of a honeycomb carrier to the radial direction, so that thermal stress is not concentrated on one part of the carrier.

Joined ranges are provided, facing each other with non-welded range therebetween, so that at least one cell located within the circumference of the same radius is overlapped. Thus, it can not be damaged or telescoped by vibration.

It is possible to fix the carrier just below the engine manifold where the carrier is exposed under the most severe conditions against thermal load and vibrations, though the temperature of exhaust gas is efficiently utilized to heat up the catalytic converter rapidly.

When a switch **58** is turned on, and an electric current is applied to both end faces of the carrier from a power supply **59**, the plane and corrugated plates **46** and **47** configuring the carrier are heated up with the slits **46a, 47a** formed thereat.

In this example, the portion of $l_4 \times l_5$ is on the order of about 1.5Ω, and a high register about 0.25Ω is formed as a whole carrier. Thus, when power about 40 A at 10 V is applied after an engine start-up, the converter is heated up to a temperature of 450° C. about 10 seconds, and the catalytic substance is activated to purify exhaust gas.

In this case, the current, which flawed into the outer circumferential ring **54b** of the carrier, when the switch **58** is on, further flows to the end faces of the carrier **45**. The current further flows in the radial direction toward the center point at the joined regions adjacent to the outer circumference and in the circumferential direction at the non-joined region.

About a flow of the current in the central part, the number of points at which the plane plate **46** can contact with the irregular portions of the corrugated plate **47**, decreases adjacent to the central portion, that is, the number of points at which welding is allowed, also decreases, so the current which flows into the radial direction, is decreased by the increase in resistance, due to non-welded portions presented at the central portion.

However, as in the fourth embodiment, almost all the central portion is a joined region, so the current from the outer circumference, flows into the honeycomb carrier **45** as if it is covered over thereby. Accordingly, the whole carrier **45** is evenly heated up to the central portion, where the flowing speed is high, so as to provide a high purification efficiency.

In the fourth embodiment as described above, a self-heat generation type honeycomb carrier has both resistances against thermal fatigue and vibration, and can achieve high purification efficiency.

FIGS. **23, 24** shows other variations according to the fourth embodiment. In this embodiment, non-joined portions are further extended up to the central portion to relieve thermal stress. Much greater thermal stress is relieved by this structure.

Especially, FIG. **24** shows an example in that non-joined portions are extended in the circumferential direction to relieve more stress in the radial direction.

Slant lines in the drawing describe a joined region between a plane and a corrugated plates.

(The fifth embodiment)

The fifth embodiment relates to a method of producing a highly durable honeycomb filter.

In the embodiment mentioned above, as showing in FIG. **3**, a plane plate **2** and a corrugated plate **3** is layered together, and then the end portions are held by winding tools *7a, 7b* therebetween. The tools *7a, 7b* are rotated on its center to wind up the both plates **2** and **3**.

However, in the fifth embodiment, another production method will be hereinafter described.

FIG. **25** shows this embodiment applied to an electric heating type honeycomb filter.

As shown in FIG. **25**, in the fifth embodiment, multiple set rolls of plane and corrugated plates are config-

ured to improve the durability of a honeycomb filter to be produced. Only one or two sets of plane and corrugated plates 2, 3 are wound about three or four times when an initial winding starts, then four to eight sets of plates 2, 3, are joined radially onto the core body 61 composed of the one or two sets of plates 2, 3, wound together, and the joined sets are wound up to the outermost circumference to have the configuration of a multiple set roll, so that its machinability and purification capacity is still kept.

According to the fifth embodiment, a length of metal foil per one set of plates 2, 3, is reduced, the thermal expansion per set is also reduced, and the deformation thereof caused by the stress vertical to the longitudinal direction of the metal foil can be deteriorated, so as to improve its durability (resistance against telescoping). One or two sets of plane and corrugated plates 2, 3 are wound about three or four times to form a core when an initial winding starts, so as to join and wind a multiple set of plates 2, 3, onto the core., Consequently, the plates 2, 3 are radially joined and wound onto the core much easier than onto a very thin central portion. Further, cells are prevented from being crushed, the plane and corrugated plates 2, 3 can be prevented from concentrating at a central portion thereof so as to break the machinability, and an increase in pressure loss is prevented.

There is no decrease in purification area and purification capacity is not easily damaged, because the central portion, in which the stream and temperature of exhaust gas are highest and efficient purification is performed, is not crushed.

According to the description above, it is possible to provide a honeycomb filter having high durability (high telescoping resistance), preferred machinability, and high purification capacity.

It will be readily appreciated that this production method is not only limited to the application to a self-heat generation type honeycomb filter, but also it is applicable to any honeycomb filter which is not a self-heat generation type.

(The sixth embodiment)

The sixth embodiment relates to a joining condition between the plane and corrugated plates.

The sixth embodiment will be hereinafter described in detail.

FIG. 26 is a type schematic view showing a honeycomb carrier 65 according to the sixth embodiment.

The honeycomb carrier 65 is configured of a plane plate 66 and a corrugated plate 67, alternately wound, each plate being shaped in belt. After that, the plane plate 66 and corrugated plate 67 are laser-welded at intervals of 2 pitches, in the all winding range where the plane plates 66 make in contact with the peak 68 and trough 69 of the corrugated plate 67, respectively, where a pitch is a interval between peaks (or troughs) on the corrugated plate. This joined point is provided adjacent to both end faces of the carrier 65, respectively, and 2 points in total are laser-welded at like peak 68 and like trough 69, respectively, along the axial direction.

Welded marks 70 after a honeycomb filter is laser-welded, are shown in FIG. 26.

This honeycomb carrier 65 is composed of Fe-Cr-Al material containing Cr; 18-24 wt %, Al; 4.5-5.5 wt %, Rare-earth metal (REM); 0.1-0.2 wt %, and Fe; the rest of all, and the material is shaped in belt and its thickness; t=0.03-0.05 mm.

A corrugated plate 67 has a wave height of 1.25 mm, a wave pitch P of 2.5 mm.

A honeycomb carrier 65 has a diameter of 86 mm, and a axial length a=14 mm.

All of welding positions l_1 and l_2 are 1.5 mm.

Effects according to this structure will be hereinafter described.

Consequently, non-joined portions are provided at intervals of 2 pitches of a corrugated plate 67, so that for example, when thermal stress is produced in the circumferential and radial directions, and further in the axial direction of the carrier 65, during heating and cooling cycle in which temperatures vary severely between 900° C. and 25° C., it is relieved at the non-joined part.

This thermal stress is produced by an outer cylinder :made of stainless steel, and mounted at the carrier 65, because the carrier 65 is restricted by the cylinder.

However, in the configuration according to the sixth embodiment, the corrugated plate can be freely modified at the non-joined parts of the plane and corrugated plates 66, 67 and the carrier 65 is held by containing honeycomb carrier 65 and this metal honeycomb carrier 65, so that thermal stress produced between an outer cylinders (not shown) is relieved in the inner carrier 65.

Accordingly, high thermal fatigue resistance is ensured.

Joining at two spots adjacent to both end faces along the axial direction of the carrier 65, allows an improvement in the rigidity of the carrier 65 itself, because t:he resonance frequency of the carrier 65 is kept at an extremely high level.

According to the configuration mentioned above, the peaks 68 and toughs 69 of the corrugated plate 67 to be joined, are formed at intervals of 2 pitches all over the region, so that the plane and corrugated plates 66 and 67 are successively joined at a certain interval, while the plates are wound.

This method can simplify the control of tools for joining.

(The seventh embodiment)

In the seventh embodiment, the joining method of the sixth embodiment, is applied to a honeycomb carrier 71 having a slit region 76 provided at the plane and corrugated plates 72 and 73 shown in the first embodiment.

As shown in FIG. 27, joining spots between the plane plate 72 and corrugated plate 73 forming a carrier 72, are laser welded at intervals of 2 pitches, where the plane plate 72 has a contact with the peaks 74 and troughs 75 of the corrugated plate 73, respectively, in the all winding range, where a pitch is a interval between peaks (or troughs) of the corrugated plate.

In the seventh embodiment, two joining spots between plates 72 and 73 are not only provided at both up and down stream sides, but also further laser-welded at like peak 74 and like trough 75, respectively, with the slit region 76 therebetween, along the axial direction as shown in FIG. 27.

A material used for the plane and corrugated plates 72 and 73 mentioned above, is the same as used in the first embodiment.

The honeycomb carrier 71 has dimensions; 66 mm in diameter and 78 mm in length of axial direction.

Welding positions from l_1 to l_6 are all 1.5 mm.

The slit region 76 is formed as shown in FIG. 28.

Each dimension: b=45 mm, c=5 mm, d=0.4 mm, e=0.4 mm, and Overall length g=25.2 mm.

Further, there are regions having f=12 mm at the up-stream side of exhaust gas, and h=40.8 mm at the down-stream side, where no slit region 76 is provided.

This slit region 76 is provided, such that an electric current is applied between both end faces of the carrier 71 in the axial direction to heat it up. The overall resistance value of the carrier 71 is 0.25Ω in the seventh embodiment, so that an electric power of 400 W at 10 V is allowed to apply.

Welding method according to the seventh embodiment will be hereinafter described in detail by reference to FIG. 29.

One out of two rolls of stainless foil, each of which is formed of a plane plate 72 cut in a predetermined width and wound in roll shape in advance, is fed between gears 77a, 77b to form a corrugated plate 73.

This corrugated plate 73 is placed over the other plane 72 plate and wound together.

Further, two beams of laser are irradiated by YAG laser heads from two directions on the extended diagonal line on a section perpendicular to the axial direction of the carrier, while the winding process is performed. Without suspension of winding operation, the peaks 78 of the corrugated plate are joined by one of the laser head, and toughs 79 of the plate 73 are by the other one, respectively together with the plane plate 72 which has a contact with the plate 73.

This laser welding should be performed at positions where the plate 72 is in contact with the plate 73, so that the positions are detected. Laser displacement sensors 81 and eddy-current displacement sensors 82 are provided for the production apparatus. Consequently, the plates are wound and joined successively without suspension of winding operation once winding process starts, while the position is detected and laser focal distance is corrected.

Namely, the laser displacement sensor 81 detects a gap between the laser head 80 and metal honeycomb carrier 71 and sends signals to a servo-motor (not shown) to move the laser head 80.

The eddy-current displacement sensor 82 detects the peaks 78 and toughs 79 of the plate 73, and YAG laser beams are irradiated in accordance with the detected signals.

The plane and corrugated plates 72 and 73 are precisely laser-welded by this way of control mentioned above.

FIG. 30 shows an illustration of laser welding.

That is, FIG. 30 shows a laser joining carried out at four spots in the axial direction.

YAG laser is divided into four beams by half mirrors 83 and sent to laser heads 80 through fiber cables, respectively, to allow this four-spots laser joining.

Other production methods such as a method of making a honeycomb carrier 71 hold catalyst therein, are the same as in the first embodiment.

As mentioned above, laser beam is divided, so as to increase the number of joining spots easily.

With this configuration, the same effect as in the sixth embodiment are obtained.

In the seventh embodiment, a rigid honeycomb carrier 71 is provided, because welding is made at positions facing each other with slit region 71 therebetween.

According to the configuration as mentioned above, the peaks 74 and toughs 75 of the corrugated plate 73 to be joined are formed at an interval of 1 pitch all over the region, so that the plane and corrugated plates 72 and 73 are successively joined at a certain interval, while the both plates are wound. This method can simplify the control of tools for joining.

For example, the laser joining as shown in FIG. 28, can be performed without suspension of winding operation.

Joining operation is easily carried out without any special complicated devices, even when both plates 72 and 73 are joined by soldering, because soldering material can be just only put on the plates at a certain interval.

(The eighth embodiment)

In the present embodiment, another embodiment of the joining methods according to the sixth and seventh embodiments, will be described by reference to FIG. 31, 32, 33, and FIG. 34.

At intervals of 3 pitches of a corrugated plate 86, 2 spots at like peak 87a and like trough 87b, respectively, are joined adjacent to both end faces of a honeycomb carrier 85 shown in FIG. 31, along the axial direction of the carrier 85.

The structure as mentioned above can provide a honeycomb carrier durable against much severe thermal stress.

A honeycomb carrier 88 in FIG. 32 has a joining part adjacent to the central portion in the axial direction of the carrier 88, in addition to the joining parts described in the sixth embodiment.

Namely, at intervals of 2 pitches of a corrugated plate 89 of a honeycomb carrier 88, like peak 91a and like trough 91b, are joined to a plane plate 90, respectively, adjacent to both end faces and central portion.

The structure as mentioned above can provide a honeycomb carrier durable against much severe thermal stress.

Joining at intervals of 3 pitches after two-spots welding as shown by welding marks 70 is carried out in a honeycomb carrier 92 shown in FIG. 33.

As shown by welding marks 70, a peak 95a and a trough 95b are not joined to a plane plate 94 at like peak 95a and like trough 95b, respectively, along the axial direction of a honeycomb carrier 93.

The structure as mentioned above can provide a honeycomb carrier still durable against much severe thermal stress.

(The ninth embodiment)

In the ninth embodiment, it is characterized that joining between the plane and corrugate plates varies in a joining rate at the positions adjacent to the central portion and circumference of a honeycomb carrier, respectively.

The configuration of a honeycomb carrier 100 other than the change in joining rate, is the same as the honeycomb carrier 71 shown in FIG. 27, so that description about the configuration is omitted, and only features according to the present embodiment will be described.

FIG. 35 shows a honeycomb carrier 100 according to the ninth embodiment.

This carrier 100 is provided in a manner that a plane plate 101 and a corrugated plate 102 are layered and wound together.

FIG. 36(a) shows a partly enlarged view of the central region 103 of the carrier 100. FIG. 36(b) shows a partly enlarged view of the outer circumferential region 104 of the carrier 100.

As shown in FIG. 36(a), all peaks 105 and troughs 106 of the corrugated plate 101 which are in contact with a plane plate 102 are laser joined in the central region 103.

As shown in FIG. 36(*b*), peaks **105** and troughs **106** of the corrugated plate **101** which are in contact with a plane plate **102** are laser joined at intervals of 2 pitches in the outer circumferential region **104**.

The joining at intervals of 2 pitches is carried out in the same manner as in the sixth embodiment.

A method of producing the honeycomb carrier **100** according to the ninth embodiment is the same as in the sixth and seventh embodiments.

Namely, in the ninth embodiment, it is characterized in that a plane plate **102** and a corrugated plate forming the carrier **100**, are changed in joining rate therebetween in the central region **103** and outer circumferential region **104**, especially it is configured that a joining rate is higher in the outer circumferential region than in the central region **103**.

When joining is made at intervals of 2 pitches, as in the sixth embodiment, sufficient strength can not be obtained, because the circumferential length is short in the central region **103**, that is, the number of joining points per round is low.

However, in the ninth embodiment, all of the points at which the plane and corrugated plates are in contact with each other, are joined in the central region **103**, such that sufficient rigidity is obtained.

There is not much affected by thermal stress in the central region **103**, so that all welded parts have a sufficient durability against thermal stress.

On the other hand, the circumferential length per round is long enough in the outer circumferential region **104**, so sufficient strength can be maintained, even when joining is made at intervals of 2 pitches. Further, the structure by joining at intervals of 2 pitches, can improve the strength against thermal stress, which is an effect provided in the sixth embodiment. Other effects of the sixth embodiment are also provided by the configuration in the ninth embodiment.

(The tenth embodiment)

FIG. 37 shows a honeycomb carrier **110** according to the tenth embodiment.

In the ninth embodiment, it is configured that joining rate between the plane and corrugated plates **101** and **102** is higher in the central region **103** than in the outer circumferential region **104**.

In the tenth embodiment, a middle region **111** other than the central and outer circumferential regions **103** and **104**, is additionally formed.

It is configured that the middle region **111** has an intermediate joining rate between the central and outer circumferential region **103**, **104**.

This configuration allows an improvement in durability for a honeycomb carrier **110** itself, and an decrease in joining rate between the plane and corrugated plates to simplify the production method.

(The eleventh embodiment)

FIGURE shows a honeycomb carrier **112** according to the eleventh embodiment.

In the tenth embodiment, the outer circumferential region **104** in the ninth embodiment is further divided into two regions as the first and second outer circumferential regions **104***a* and **104***b*, respectively.

Namely, a plane plate and a corrugated plate (not shown) are joined at an interval of a pitch in the central and first outer circumferential region **104***a*. They are joined at intervals of two pitches in the region **104***a*.

This configuration facilitates to set soldering material in joining operation of the corrugate and plane plates by soldering.

(The twelfth embodiment)

In the twelfth variations, another embodiment in the ninth, tenth, and eleventh embodiments, will be hereinafter described.

In the ninth embodiment, all peaks **105** and troughs **106** in the central region **103** are joined with the plane plate **101**, and they are joined at an interval of one pitch in the outer circumferential region **104**.

However, the plane and corrugated plate **101** and **103** may be joined at intervals of two pitches in the central region **103**, and at intervals of three pitches in the outer circumferential region **104**.

Further, the peaks **105** and troughs **106** of the corrugated plate **101** are joined respectively at a interval of one pitch and intervals of two pitches in the central region **103**. Namely, two peaks **105** out of three peaks **105** and two troughs **106** out of three troughs **106** of the corrugated plate **101** are joined. The peaks **105** are joined alternately by every one peak and two peaks with the plane plate **102** in the outer circumferential region **104**. The troughs **106** may be also joined alternately by every one trough and two troughs.

(The thirteenth embodiment)

FIG. 39 shows the thirteenth embodiment.

The present embodiment relates to a method of holding an outer cylinder containing a honeycomb carrier according to the embodiment mentioned above.

The thirteenth embodiment will be hereinafter described in detail.

A honeycomb carrier **105** with catalyst supported therein is the same configuration as the honeycomb carrier **1** according to the first embodiment.

Rings **106***a* and **106***b* which become base when fixed, are joined at end portions **105***b* having no slits **105***a* of the carrier **105**, as shown in FIG. 39.

These rings made of stainless steel plate with a thickness of more than 1 mm, are joined completely or partly to the both end portions **105***b* of the carrier **105** by means of soldering, laser-welding, or spot welding.

The carrier **105** having a function as a catalytic converter is provided through a series of procedures for the catalytic honeycomb carrier such as r, aluminum coating after the rings **106***a* and **106***b* are joined.

Two bar-like supporting members **108**, are joined into the ring **106***a* and **106***b* on the up-stream and downstream sides, respectively, so as to fix the carrier **105** and outer cylinder **107** by four members in total.

The outer diameter of the cylinder **107** is greater than of the carrier **105**, rings **106***a* and **106***b*. The cylinder **107** is divided into two portions at the side face in accordance with the number of the supporting members **108** and their locations to be fixed. Notches **108***a* are formed at positions which are in contact with the members **108** of the cylinder **107**, so as to facilitate to fix the members **108**.

This structure make it possible to assemble a catalytic converter easily.

Filler **109** having adiathermanous, air-tightness, and buffer action, is provided onto the inner wall of the cylinder **107**, so that problems such as vibrations of the carrier **105** by a flow of exhaust gas and an engine, blowing-through of unpurified gas, and thermal radiation from the carrier **105**, are reduced or overcome.

The use of the filler **109** accelerates an improvement in durability and purification capacity.

Operation according to the thirteen embodiment will be hereinafter described.

When exhaust gas from an engine (not shown) comes into the catalytic converter **110** according to the thirteen embodiment, the honeycomb carrier **105** is heated up to be a high temperature state by temperatures of the gas itself and catalytic reaction.

A normal honeycomb carrier **105** has no expandability on its own. Such carrier **105** is rigidly joined to the cylinder, so stress caused by thermal expansion acts on the carrier to produce telescoping and deformation of the honeycomb body.

The temperature distribution caused by a difference in thermal capacity between the honeycomb carrier and outer cylinder is also affected on the decrease in durability.

However, in a method of holding the carrier **105** with the cylinder **107** in the thirteenth embodiment, thermal expansion of the carrier **105** is absorbed by slits **105***a* formed at the carrier **105**, so as to reduce the production of stress.

Further, heat by the thermal conductivity from the carrier **105** to cylinder **107**, is conducted only through the thin supporting members **108**, so the thermal capacity is extremely small, and the thermal distribution in the carrier **105** can be also maintained to be small. Therefore, high durability is realized with both method and slits **105***a* provided for the carrier **105**.

On the other hand, catalytic element is not yet activated yet and unpurified gas is exhausted when catalyst is cold just after start up, though, the unpurified gas will be reduced to improve the purification efficiency as a whole, if the activation speed is more accelerated.

As in the thirteenth embodiment, if the slits **105***b* are formed at the carrier **105**, thermal capacity will be reduced to hasten the increase in temperature from idling condition and improve the purification performance with the thermal conductivity to the cylinder **107** kept in low level.

(The fourteenth embodiment)

FIG. **40** shows an example applied to a self-heat generation type converter **115**.

Slits **116***a* are formed at this self-heat generation type honeycomb carrier **116**, and rings **106***a* and **116***b* which are used in the thirteenth embodiment, are also provided at an end part **116***b* of the carrier **116**.

Two supporting members **117** according to the fourteenth embodiment, are joined to the rings **116***a* and **116***b*, respectively, that is, four members in total are used.

A threaded portion is formed at each supporting member **117**. A supporting bar **120** is coupled to the threaded part **117***a* through an insulating washer **118** and a nut **119**.

With this configuration, the supporting members **117** and supporting bars **120** are fixed to the outer cylinder **121** through the insulating washer **118**.

Operation according to the fourteenth embodiment will be hereinafter described.

An electric current is applied to the honeycomb carrier **116** through between the supporting members **117** and supporting bars **120** when catalyst is not sufficiently activated just after an engine (not shown) is started up.

The current flows in the axial direction of the carrier **116**, that is, from the up-stream side to the down-stream along a flow of exhaust gas.

The honeycomb carrier **116** having slits **116** by which high resistance, low thermal capacity, and less heat conducted to the outer cylinder **121** are provided, can raise temperature evenly for a short time, and activate catalyst, so that purification for exhaust gas is available in tens of seconds after started up, and high purification efficiency is achieved. Further, durability is also improved.

In the fourteenth embodiment, the supporting member **117** and supporting bar **120** are fixed in insulation with the outer cylinder **121** by means of the insulating washers **118** and nuts **119**, though, it is not limited to this way.

The use of supporting members and bars which are made of insulating materials such as inorganic fiber materials, are preferably required for the self-heat generation type honeycomb carrier as the fourteenth embodiment.

The shape of a member for joining the honeycomb carrier and supporting members can not be limited to a ring shape, so that it could be, one not closed in a circumferential shape, with a cut-away portion to have expandability, or divided into more than two portions.

The cross section of the supporting member can be arbitrary shaped, though, preferably, smaller cross-sectional area is required to reduce the thermal capacity and thermal conductivity as far as the sufficient strength is ensured.

(The fifteenth embodiment)

FIG. **41** is a type schematic view showing a honeycomb carrier **125** according to the fifteenth embodiment.

An outer cylinder **126** is provided partly or circumferentially at an end portion **125***a* of a honeycomb carrier **125**.

This cylinder **126** is fixed at the carrier **125** by means of brazing or laser welding. This outer cylinder **126** is provided with a through member **127**.

This through member **127** is six pieces in total, and each piece extends into the inner circumference of the cylinder **125**. This member **127** is joined with the cylinder **125** by means of electric discharge welding, laser welding, soldering or the like.

Mainly, vibrations of the carrier **125** in the axial direction (a direction) are supported by the through members **127** internally extending into the honeycomb carrier **125**.

As described above, the outer cylinder **126** and honeycomb carrier **125** are joined in a fit-in relationship by the through members **127**.

Each linear thermal expansion coefficient for the through members **127** and honeycomb carrier **125** is nearly equalized by this configuration, so as to reduce the thermal stress produced on heat-cycle movement.

In the fifteenth embodiment, the through member **127** has a pin-like and a diameter of 3 mm, and there are six pins on the same face (at regular intervals), twelve pins in total for the all honeycomb carrier **125**. A hole of the carrier in which a pin is inserted, is machined into a diameter of 2.9 mm by electric discharge machine.

In the fifteenth embodiment, the outer cylinder **126** is shaped in ring, though, it is not limited to this shape, for example, as in shown in FIG. **42**, a set of outer cylinder **128** divided into more than two pieces may be employed.

In FIG. **42**, the through member **127** extends in the direction of the central axis of the honeycomb carrier **125**, though, as shown in FIG. **43**, a through member **129** extending at an angle of a° ($0 <= a° <= 70$) with the direction of the central axis perpendicular to the plane and corrugated plates forming the carrier, may be employed.

In FIG. 41, the through members **127** extend from different locations, respectively, though, as in FIG. **44** A plurality of through members **130** extending from a location may be employed.

The cross sectional shape for the through member is preferably a circle, though, it may be a polygon, or an oval.

By the use of the fifteenth embodiment, a honeycomb carrier for exhaust gas purification catalyst having a high durability against thermal stress produced upon heat-cycle process, is provided.

(The sixteenth embodiment)

The sixteenth embodiment according to the present invention, will be hereinafter described in detail.

FIG. **45** is a type view of an exhaust gas purification honeycomb carrier according to the sixteenth embodiment.

An exhaust gas purification catalytic converter **135** according to the sixteenth embodiment, includes a honeycomb carrier **136** which is made of a plane plate and a corrugated plate, the plates being layered together and wound in spiral shape, a supporting member **137** cut in ring shape, a housing **138** containing the carrier **136**, and coupling member **139** with which the carrier **136** is fixed in the housing.

A joining part **140** at which the supporting member **137** and carrier **136** are joined by laser-welding, soldering or the like, is formed at a part of the contact surface between the supporting member **137** and carrier **136**. The coupling member **139** fitting in through the housing **138** makes contact with a part of the other surface of a surface facing the joining portion **140** of the supporting member **137**.

Then, a joining portion **141** joined by welding is formed at the portion of the housing through which the coupling member **137** goes in.

As shown in FIG. **45**, this joining portion **141** and the other joining portion **140** between the supporting member **137** and honeycomb carrier **136**, are preferably not on the same radius, so that thermal stress is relieved by elasticity of the supporting member **137**.

The honeycomb carrier **136** is fixed in the housing through the supporting member **137** and coupling member **139**.

In the exhaust gas purification catalytic converter **135** according to the sixteenth embodiment, as described above, the supporting member **137** is partly made in contact with the outer circumference of the carrier **135**, that is, all the outer circumference is not covered, so that the degree of freedom in the radial and circumferential directions is high and thermal stress produced on heat-cycle process is small.

The configuration is also very simple and a high durability is ensured.

(The seventeenth embodiment)

In the seventeenth embodiment, another embodiment in the sixteenth embodiment will be described.

In the sixteenth embodiment, the honeycomb carrier **136** is fixed at the housing **138** through the supporting members **137** and coupling members **139**.

In the seventeenth embodiment, as shown in FIG. **46**, it is fixed at a housing **138** only through supporting members **137**.

In this case, a joining portion **141** which is partly joined is formed.

In FIG. **46**, each of the joining portion **140** and **141** is not on the same radius by the same reason in the sixteenth embodiment.

When a honeycomb carrier **136** is short in the axial direction, a supporting member extends over both end portions as shown in FIG. **47**. When a carrier **136** is long in the axial direction, a supporting member **137** may be divided as shown in FIG. **48**.

In the sixteenth embodiment, the supporting member **137** has a shape obtained when a ring is cut into pieces, though, it is possible to reduce thermal stress produced with a ring-like supporting member **142** shown in FIG. **49**, if the member **142** is partly welded. The use of a supporting member having a partly cut away portion **143** as shown in FIG. **50**, allows the relief of thermal stress with elasticity thereof.

A supporting member **145** may be a ring shaped in zigzag pattern as shown in FIG. **51**.

Further, how the honeycomb carrier according to the fourth embodiment is held in the housing, will be described hereinafter by reference to FIG. **52**.

In this case, joining portions **140** between supporting members **137** and a honeycomb carrier **45** are formed onto the portions of the outer circumference, respectively, away from the outermost circumferential portions of the first, second, and the third regions **49**, **50**, and **51**, in which a plane plate and a corrugated plate forming a honeycomb carrier **45** are welded adjacent to the outer circumference.

This structure allows the reduction in stress produced around the outermost circumference by the elasticity of the non welded portions on the outer circumference of the carrier **45**.

A converter may be provided by folding supporting members **146** alternately to the carrier side, as shown in FIG. **53**.

This structure also allows the reduction in thermal stress by the elasticity of the supporting members **42**.

By the use of the seventeenth embodiment as described above, a honeycomb carrier for exhaust gas purification catalyst having less thermal stress produced upon heat-cycle process, a high durability, and a simplified structure, is provided.

(The eighteenth embodiment)

FIGS. **54** and **55** show this embodiment.

In the eighteenth embodiment, an embodiment relates to a structure holding the honeycomb carrier **1** shown in the first embodiment, into an outer cylinder.

A main monolith **151** is provided at the down-stream of a honeycomb carrier **150** in FIG. **54**.

The carrier **150** and main monolith **151** have the same structure as described in the first embodiment. Namely, the carrier is configured of the plane and corrugated plates having slits partly.

Features according to the eighteenth embodiment, will be hereinafter described.

In the present embodiment, an outer cylinder **152** is provided, so as to contain a honeycomb carrier **150** therein. Two types of heat insulators **153**, **154** are filled between the carrier **150** and cylinder **152**.

The heat insulator **153** is provided to cover the carrier **150** directly, and expose itself to exhaust gas directly, and the material is made of an inorganic long-staple fiber.

The heat insulator **154** is provided to cover the outer surface of the heat insulator **153**, and made of a group of inorganic short-staple fibers.

These heat insulator **153** and **154** may be mixed with a material having a thermal expansibility such as vermiculite.

The up-stream side of the carrier **150** is electrically connected with the outer cylinder **152**, and the ground.

An electrode **155** is inserted into the carrier **150** through the cylinder **152** and electrically connected with the, down-stream side of the carrier **150** directly. The electrode **155** and cylinder **152** are electrically insulated by an insulator **156**. An electric current is applied from a lead line **157** to the down-stream of the carrier **150** through the electrode **155**.

Operation according to the eighteenth embodiment will be hereinafter described.

An electric current is applied when the main monolith. **151** is not activated yet just after an engine (not shown) starts up.

The honeycomb carrier **150** having slits can increase resistance higher and make the thermal capacity extremely smaller. Therefore, when the current is applied to the carrier **150**, the carrier **150** is smoothly raised in temperature, so that catalyst held at the carrier **150** is also activated for a short time. Accordingly, the unpurified gas of exhaust gas from an engine just after started up, can be reduced into a small amount.

The heat insulators **153** and **154** are provided to prevent heat of the carrier from leaking to the cylinder **152** in the eighteenth embodiment, so as to accelerate the increase in temperature. The heat insulator **153** and **154** are flexible and elastic enough to hold the carrier **150** with the all side face, so as to protect the carrier from vibration.

The effect is greater if the heat insulators **153** and **154** are mixed with a heat expansible material.

The heat insulator **153** is a woven cloth made of long fiber, and provides high durability against wind loss, high adiathermanous, so as to prevent the heat insulator **154** which is weak against wind-loss and blow-through, from being scattered in the exhaust gas. With the structure as described above, heat produced by electrically heating the carrier **150** and heat of catalytic reaction are conducted to the main monolith **151** by a flow of exhaust gas, when the temperature of the carrier **150** is raised to be in a state of activation, so that the, activation of the carrier is further accelerated to reduce gas which is exhausted as unpurified gas.

(The nineteenth embodiment)

The present embodiment relates to a structure which holds an electrode for supplying power to a honeycomb carrier.

In FIG. **56**, an outer cylinder **161** is provided to hold a honeycomb carrier **160** therein through a heat insulator **162**.

An opening **161a** is formed at a part of the cylinder **161**. An electrode **163** having a stopper surface for fixing a nut is inserted through the opening **161a**, so that the end face **163a** of the electrode **163** and the carrier **160** are welded together to have an electric contact each other.

This electrode **163** is fixed at the outer cylinder **161** in the following in manner.

Namely, a flange **163b** is united at the electrode **163** in one body. A first insulating material **164**, a mount **165**, a washer **166**, a second insulating material **167**, and a washer **168** are successively layered from the circumference of the carrier **160** at the carrier side of the flange **163b** as shown in FIG. **56**.

This layer is locked with a nut **169** from the other side of the flange **163b** opposite to the carrier side.

By the use of this structure, the electrode **163** is electrically insulated with the cylinder **161**.

The mount **165** is the same in diameter as the opening **161a** machined at the cylinder **161**.

According to the nineteenth embodiment, airtightness, and resistance against vibration from an engine are ensured, and the electrode **163** is fixed at the mount **165** by the axial force durable against the thermal deformation of the cylinder **161** upon engine heating-cooling cycle. Then, the electrode **163** is fixed in welding with the cylinder **161** by the mount **165**, so that it is fixable without deformation of the carrier **160** by a predetermined torque.

By the use of the nineteenth embodiment as described above, a self-heat generation type catalytic converter with which durability, air-tightness, and resistance against vibration are ensured, is provided.

In this embodiment, the mount **165** is the same in diameter as the opening **161a** machined at the cylinder **161**, though the bore diameter of the opening **161a** may be machined larger than that of the mount **165**.

Namely, If the bore diameter of the opening **161a** is machined greater than that of the mount **165**, the location of the electrode will be shifted in the axial or circumferential direction of the carrier **160** to fix it, in case of thermal deformation is produced by welding the flange **170**, **171** when the mount **165** is fixed in welding at the cylinder **161**. Consequently, no stress is affected radially or axially on the honeycomb carrier, so that deformation of the carrier is prevented.

What is claimed is:

1. A self-heat generating honeycomb filter mounted in an exhaust pipe line of an engine and including a plane plate and a corrugated plate, said honeycomb filter comprising:
   a portion having a plurality of openings formed in at least a part of at least one of said plane plate and said corrugated plate, said plates being constructed and arranged to permit electric current to flow either from an up-stream side end portion of said filter to a down-stream side end portion thereof or from a down-stream side end portion of said filter to an up-stream side end portion thereof.

2. The honeycomb filter according to claim 1, wherein said plane and corrugated plates are wound into a cylindrical shape.

3. The honeycomb filter according to claim 1, wherein at least one of said plates include input/output portions constructed and arranged such that an electric current can be applied to said portion.

4. The honeycomb filter according to claim 1, wherein at least one of said plates includes a region where said openings are not provided, said region being formed at an up-stream side end portion and a down-stream side end portion of at least one of said plane plate and corrugated plate for coupling to said exhaust pipe line of the engine.

5. The honeycomb filter according to claim 1, wherein openings of said portion at boundary regions thereof and at said end portions are smaller than openings of said portion at other regions thereof.

6. The honeycomb filter according to claim 1, wherein only said end portion of said plane plate or corrugated plate has catalyst supported thereon.

7. The honeycomb filter according to claim 1, wherein only said up-stream side end portion of said plane plate or corrugated plate has no catalyst supported thereon.

8. The honeycomb filter according to claim 1, wherein said plane plate and said corrugated plates are

joined at joining points such that the joining points between the plane and corrugated plates at the central region of said honeycomb filter are greater than that at an outer circumferential region thereof.

9. The honeycomb filter according to claim **1** or **2**, wherein the plane and corrugated plates are alternately laminated on each other.

10. The honeycomb filter according to claim **4**, wherein said portion is formed at an up-stream side of the plane and corrugated plates in the axial direction thereof.

11. The honeycomb filter according to claim **5**, wherein said plane plate and said corrugated plate are coupled such that the plane plate and corrugated plate which are laminated on each other are joined at every second point of contact therebetween along a joined portion thereof.

* * * * *

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United States Patent [19]

Finley

[11] **Patent Number: 5,425,924**

[45] **Date of Patent: Jun. 20, 1995**

[54] **COMPACT FIXED-BED REACTOR WITH FOLDED REACTION PATH**

[76] Inventor: **Charles M. Finley**, 300 W. Lemon Ave., Arcadia, Calif. 91007

[21] Appl. No.: **117,468**

[22] Filed: **Sep. 7, 1993**

[51] Int. Cl.⁶ **B01J 8/02**; B01J 19/30; B01J 35/02

[52] U.S. Cl. **422/220**; 55/308; 55/444; 55/445; 96/152; 422/176; 422/177; 422/228; 422/238; 422/239; 422/311

[58] **Field of Search** 422/168, 176, 177, 188–191, 422/193, 195, 211, 220, 224, 225, 228, 236, 238, 239, 311; 60/299–302; 55/444, 308, 442, 445; 56/107, 152; 96/129, 154

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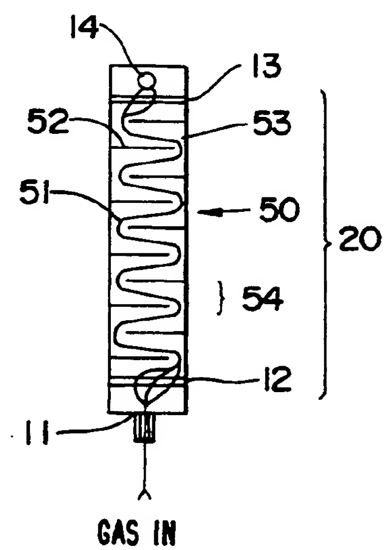
Primary Examiner—Robert J. Warden
Assistant Examiner—L. M. Crawford
Attorney, Agent, or Firm—W. Wayne Lianh

[57] **ABSTRACT**

A compact fixed-bed catalytic reactor containing a plurality of staggered partitioning plates inside a reactor vessel to form a folded reaction path. The reactor is substantially rectangular in shape and each of the partitioning plates is held inside the reactor by a frictional force between the partitioning plate and the inner wall of the reactor vessel while one side thereof, being shorter than the width of a corrsponding inner side the reactor, forms an opening allowing the passage of reactant therethrough. The partitioning plates contain a plurality of fingers to further secure the same in place and prevent horizontal movement thereof. The present invention allows a box-like catalytic reactor to provide the advantages of a fixed-bed tubular reactor, while maintaining a desirable spacial compactness and lowering the construction cost.

15 Claims, 5 Drawing Sheets



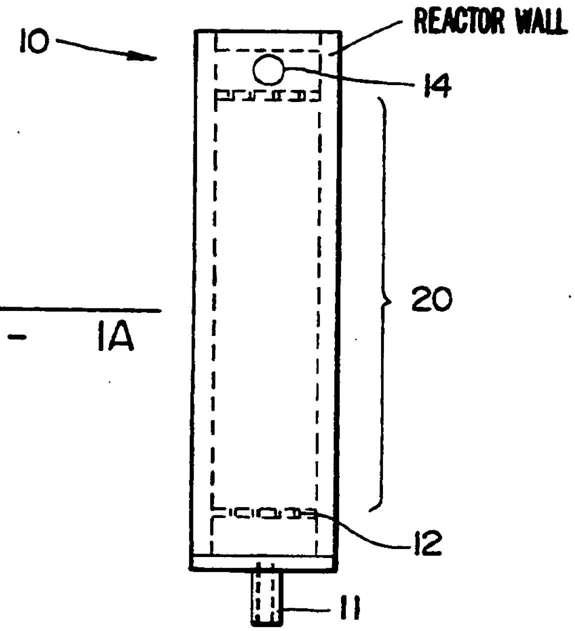


Fig - 1A

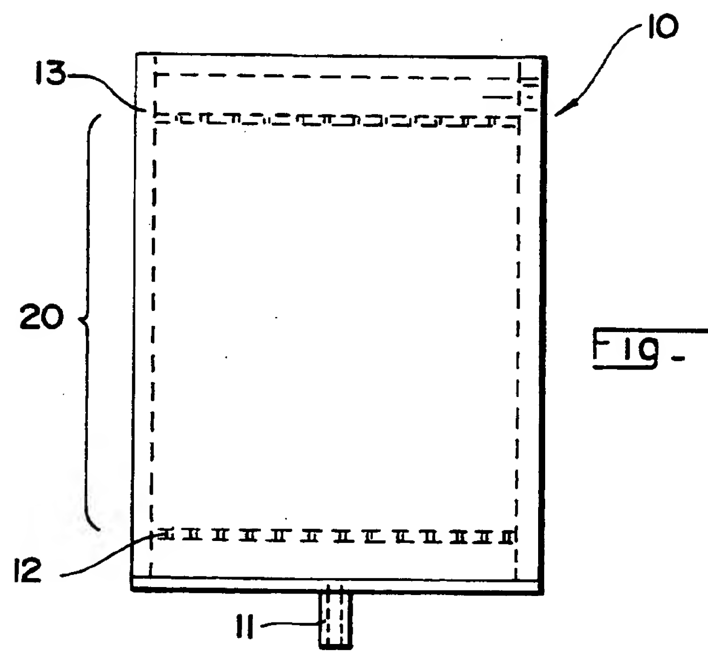


Fig - 1B

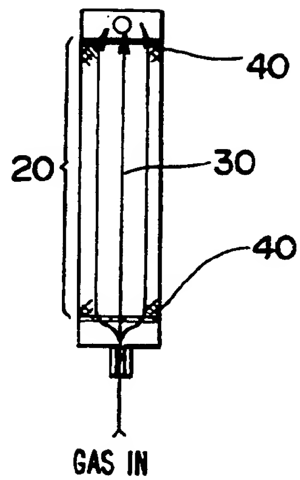


Fig- 2A

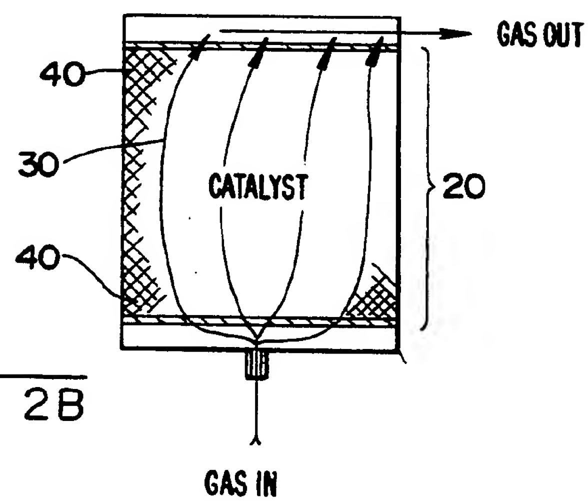


Fig- 2B

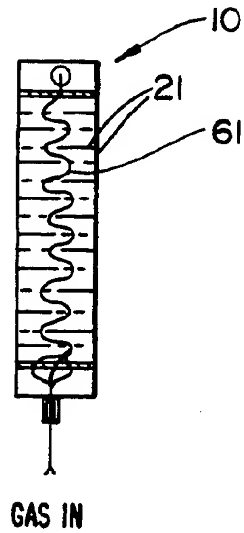


Fig- 3A

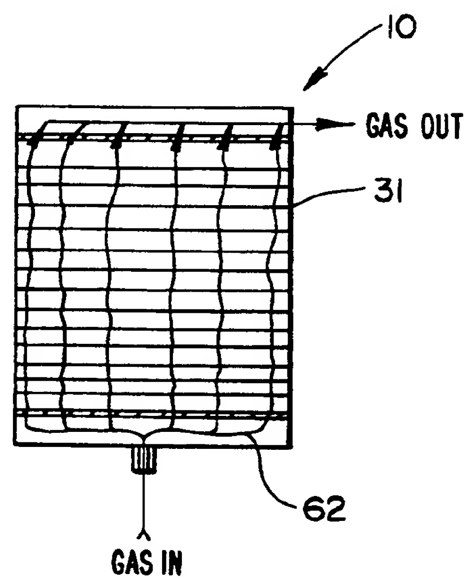


Fig- 3B

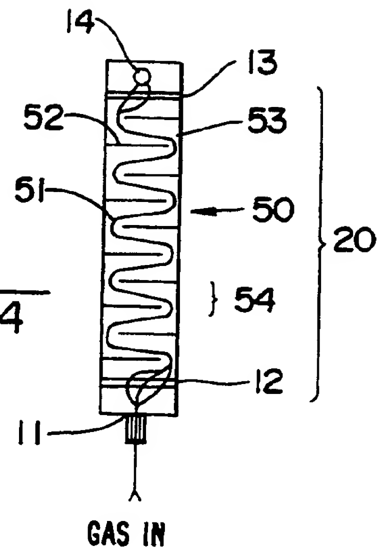


Fig- 4

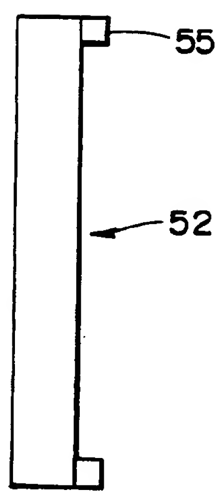


Fig- 5B

Fig- 5A

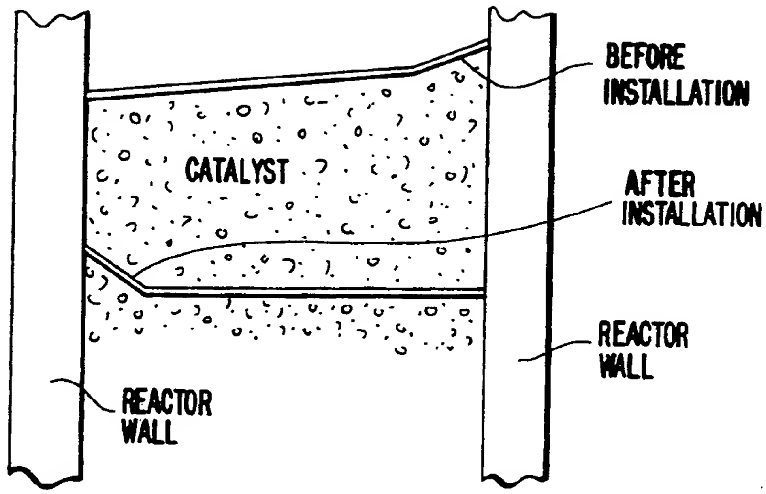

BEFORE INSTALLATION
CATALYST
AFTER INSTALLATION
REACTOR WALL
REACTOR WALL

Fig- 6

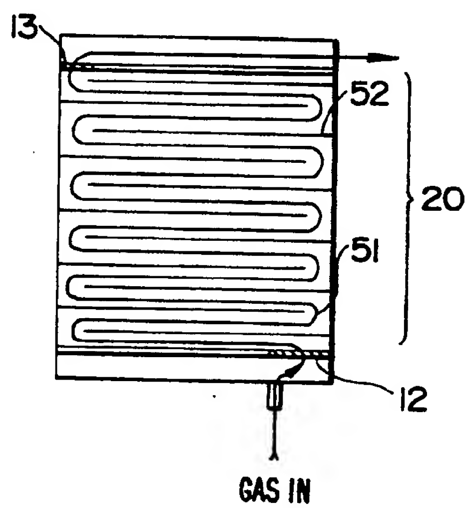

13
52
20
51
12
GAS IN

Fig- 7

COMPACT FIXED-BED REACTOR WITH FOLDED REACTION PATH

FIELD OF THE INVENTION

This invention relates to a box-like catalytic reactor that provides the characteristics and advantages of a fixed-bed tubular reactor, or in the alternative, a fixed-bed tubular reactor that has the compactness of a box-like reactor. More particularly, this invention relates to a fixed-bed catalytic reactor having a folded reaction path so as to provide an elongated and well-defined flow path through which the reactant molecules must travel. The folded reaction path of the present invention allows the reactants to travel through the reactor with an increased linear speed at the same space velocity while, at the same time, it maintains a generally uniform path length for each reactant molecule, maximizes reaction conversion, minimizes the occurrence of side-reactions, and prolongs the life of catalyst.

BACKGROUND OF THE INVENTION

Catalytic reactions involving gaseous reactants are often conducted in fixed-bed chemical reactors filled with an appropriate catalyst. Because of the high mobility of gas, the fixed-bed reactors designed for gaseous reactants typically consist of a multiplicity of long, small-bore tubes, each in the form of a packed tubular reactor, in order to provide the resident time required to achieve a desired reaction yield and minimize the extent of undesired channelling. An ideal tubular reactor is designed such that it approximates a plug flow type reactor with minimum amount of mixing, and each reactant molecule travels approximately the same length in the reactor.

A typical tubular reactor for gaseous reactants can be only several inches in diameter, but many feet long. Because of the great dimensional asymmetry of tubular reactors and the relative high cost of construction thereof, it is desirable to modify a tank- or vessel-type chemical reactor so that it provides many of the desired characteristics and advantages of a tubular reactor while maintaining the dimensional compactness and allowing a lower construction cost. Vessel- or tank-type reactors are known to cause channelling, back-mixing, non-uniform resident time, etc., among a number of other problems such as low linear velocity.

U.S. Pat. No. 2,690,267 issued to Miller et al. discloses a catalyst loading and baffle by which a plurality of baffle plates in the shape of truncated circles are inserted into corresponding grooves inside the reactor to reduce the extent of channelling. The baffled reactor disclosed in the '267 patent does not provide a uniform path length for the reactant molecules. Because of the circular cross-section of the reactor, some reactants travelling near the center of the reactor (horizontally) will have a shorter path length than those travelling near the edge of the reactor, thus resulting in non-uniform resident times for the reactants and possibly low reaction yield and/or side products.

U.S. Pat. No. 3,898,049 issued to Burroughs, et al. discloses a hydrogenation reactor comprising an elongated vertical container and a plurality of vertical baffles dividing the container into a plurality of vertical compartments thus increasing the height-to-width ratio of the reactor and allowing the linear velocity of the flowing reactants to be increased to several times that of a single pass reactor. One of the disadvantages of the

compartmentized reactor disclosed in the '049 patent is that, in half of the compartments, the gaseous reactants must travel downward. Furthermore, because all the radially disposed compartments adjoin the same core compartment, leakage may become a concern. Also, the compartments do not have the same cross-sectional areas, thus resulting in non-uniform flow paths for the gas reactants

U.S. Pat. No. 2,127,561 issued to Herman discloses a heat exchange catalytic converter which contains a plurality of paired catalyst passages. The entering gases are led into the reactor which pass upwardly through one set of passages then downwardly through another set of passages. Because of the heat liberated by the exothermic reaction, the catalyst at an inlet zone will be heated by the contiguous catalyst at an exit zone. U.S. Pat. No. 1,945,353 issued to Jaeger discloses a similar multiple-path reactor to effect heat exchange between catalysts in different paths.

U.S. Pat. No. 2,120,538 issued to Andrews discloses a vapor phase oxidation reactor which contains a plurality of staggered shelves, on which is placed a vanadium oxide catalyst. The vapors pass downwardly over the catalyst. U.S. Pat. No. 3,048,468 issued to Watkins discloses a similar catalytic reactor containing a plurality of staggered shelves, on which the catalyst is placed. Inert particles are heated and introduced into the reactor which travel counter-currently to the reactants to effect heat transfer. U.S. Pat. No. 3,506,408 issued to Kageyama, et al., also discloses a reactor containing similarly staggered catalyst shelves.

U.S. Pat. No. 4,590,044 issued to Mos, et al., discloses a multistage reactor containing a number of radially disposed ring-shaped lamellae of two different sizes. The smaller lamellae contact the central inlet tube but do not contact the inner shell of the reactor and the larger lamella contact the inner,shell but do not contact the inlet tube. The smaller lamella alternate with the larger lamella so that a zig-zag path is formed in the reaction space.

SUMMARY OF THE INVENTION

The primary object of the invention is to develop a fixed-bed, or packed, catalytic reactor with folded reaction path Which provides the advantages and characteristic of a linear, tubular reactor, while maintaining a substantially more compact reactor dimension and allowing simplicity of construction.

In a preferred embodiment of the present invention, the reactor comprises a substantially rectangular reactor vessel and a plurality of spaced apart, substantially identical partitioning plates fixedly attached to the inner wall of the reactor in a staggered manner so as to form a folded reaction path inside the reactor. Each of the partitioning plates has a dimension by which one side thereof is substantially equal to but only slightly less than the corresponding inner side of the reactor, whereas the other side of the partitioning plate is shorter than the corresponding inner side of the reactor vessel. The partitioning plates are placed inside the reactor vessel in such a manner that three sides thereof tightly adjoin the inner wall of the reactor vessel, while a gap is formed between the forth side of the partitioning plate and the inner wall of the reactor vessel to thereby create an opening allowing the reactant gas to travel therethrough. The partitioning plates are designed with such a dimension so that they can be se-

cured inside the reactor vessel by the frictional force. However, other means can be provided to further, or in lieu thereof, secure the partitioning plates to the reactor wall.

Optionally, a finger or a plurality of fingers can be provided as extension of the partitioning plates so that the aggregate length of the shorter side and the finger matches that of the inner dimension of the reactor to allow for a firm grip of the plates inside the reactor. In an alternate embodiment, the fingers can be made to be slightly longer than the width of corresponding inner side of the reactor. The fingers can be bent to allow the partitioning plates to be firmly secured inside the reactor. The existence of these fingers also prevents the horizontal movement of the partitioning plates, thus ensuring a consistent folded reaction path for the reactants. Furthermore, a plurality of grooves may be provided on the inner wall of the reactor vessel to allow the partitioning plates to be snapped thereto as an additional, or alternate, securing means.

One of the main advantages of the present invention is that it provides an elongated and relatively uncommingled flow path for the reactant molecules, similar to that provided by a tubular reactor. The paths travelled by the reactant molecules are essentially parallel to each other, as well as parallel to the partitioning plates and the rectangular walls of the reactor vessel that define each catalyst region. The reactor of the present invention differs from a baffled reactor in that, among other things, it provides a well-defined flow path. In many baffled reactors, the flow path could vary depending on the reactant flow rate and/or the pressure drop across the catalyst bed. Furthermore, in baffled reactors, the paths travelled by reactant molecules often cross each other. More particularly, the flow paths in the baffled reactor do not resemble the parallel pattern provided by the present invention, thus often causing mixing between reactants and products resulting in undesired side products.

Since the reactor of the present invention is functionally similar to a tubular reactor, it has many of the characteristics of a tubular reactor. With the present invention, high gas linear velocities can be maintained without compromising the resident time of the reactants. In a strongly exothermic reaction, this aids in "spreading out" the large amounts of heat which are generated by the reaction. Failure to limit the extent of such heating can result in localized temperatures high enough to damage the catalyst and to produce excessive amounts of by-products as well. Also, the increased linear velocity and the reduced cross-section area, as well as the increase length, of the flow path allows a higher back-pressure at the inlet and inside the catalyst bed to be maintained. This is advantageous as it forces the gas reactants to spread out more within the catalyst bed, resulting in improved utilization of the catalyst bed and less chance that stagnant areas may exist.

It is preferred that the partitioning plates be made of metal so as to facilitate the conduction of heat back to the wall of the reactor vessel, and thereby to help make the internal temperature of the reactor more uniform. This, in itself, improves reaction yield because more of the catalyst/gas interfaces can be held at or near the optimum temperature for best yield. Hot spots and the resultant coking and/or other damages to the catalyst are also minimized with the present invention due to significantly improved thermal transfer within the bed.

The reactor of the present invention provides many of the advantages of a tubular reactor but with a more compact physical dimension. More particularly, it does not have the situation wherein one dimension (length) is unproportionately greater than others. For example, with a ten-fold path, a reactor of the present invention having a width of 12 inches is equivalent to a tubular reactor having 10 feet in length. Although a tubular reactor may be bent to reduce its physical dimension, doing so, however, will cause problems in repacking the reactor, and is generally not desirable.

Another advantage of the present invention over a conventional tubular reactor is that, if desired, the cross-section of the bed can be varied, and the gas linear velocity can be changed accordingly, by having larger spacings between the partitioning plates in one part of the bed than those in another part. This feature might be used to spread out the initial exotherm by having a very high velocity in the first section, than widening the spacings between the partitioning plates for subsequent parts of the bed where the reaction rate is lower and, therefore, a longer contact time between the reactants and the catalyst is desired. This would allow maximum conversion of the remaining reactants while keeping the initial exotherm within design limits. It would be considerably more difficult, if possible, to attempt to create the same variation in the cross-sections of a tubular reactor.

BRIEF DESCRIPTION OF THE DRAWINGS

The objects and advantages of the present will become more apparent upon reading the following detailed description and upon reference to the drawings in which:

FIGS. 1A and 1B are a side view and a front view, respectively, of a rectangular tank-type fixed-bed reactor without the partitioning plates.

FIGS. 2A and 2B are a side View and a front view, respectively, of a typical flow pattern inside a rectangular tank-type fixed-bed reactor without the partitioning plates.

FIG. 3A is a side view of a typical flow pattern inside a rectangular tank-type fixed-bed reactor with baffles.

FIG. 3B is a front view of a typical flow pattern inside a rectangular tank-type fixed-bed reactor with slot liner plates.

FIG. 4 is a side view showing a typical flow pattern inside the fixed-bed reactor of the present invention containing staggered partitioned plates.

FIGS. 5A and 5B are a side View and a front view, respectively, of a rectangular partitioning plate having two finger at both ends.

FIG. 6 is a side view of a portion of the fixed-bed reactor of the present invention containing fingered partitioning plates.

FIG. 7 is a side view of an alternative embodiment of the present invention in which the gas reactants travel along the long side of the reactor vessel thus creating an extremely long reaction path.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Now referring to the drawings. In FIGS. 1A and 1B, it is shown a side view and a front view, respectively, of a rectangular box type reactor vessel 10 packed with catalysts in its catalyst region 20. The dimensions of the box-type reactor are 24" (height)×12" (width, or first width)×2" (depth, or second width). The reactor is

packed with an appropriate catalyst to carry out desired chemical reaction. Reactants enter the reactor via an inlet 11. A perforated plate 12 is placed between the inlet 11 and the catalyst region 20 to provide support and facilitate uniform distribution of reactants into the catalyst region 20. A similar perforated plate 13 is also provided between the catalyst region 20 and the outlet 14, to further improve the distribution of reactants in the catalyst region 20.

FIGS. 2A and 2B show the side view and front view, respectively, of a typical gas flow pattern across the catalyst region 20. The gas flow path 30 is limited to the length of the catalyst region 20. As indicated in FIGS. 2A and 2B, because of the relatively low ratio between the length of the flow path and its cross-sectional area, a significant portion of the catalyst region 20 becomes "dead spots" 40 wherein poor or zero gas flow exists, thus creating regions of inhomogeneity inside the reactor. Furthermore, because of the need to provide the required resident time in order for the .gas reactants to achieve a desired conversion rate, a relatively low gas flow rate, and consequently a relatively low pressure, must be maintained in the reactor. This further amplifies the inhomogeneity problem of the box type reactor shown in FIGS 1A and 1B. Inhomogeneity in the fixed bed causes inefficient use of the catalyst and shortens the life thereof; it could also result in undesired by-products.

FIG. 3A shows that the flow path in the box type reactor may be increased by inserting a plurality of conventional baffles 21 along the flow path in the reactor vessel 10. Some improvements were observed with the implementation of the baffles 21 relative to the reactor shown in FIGS. 2A and 2B. However, the existence of the baffles 21 created many separate commingling flow paths of the reactants and a substantial extent of undesired mixing between product streams and reactant streams. Furthermore the increase in reaction path is limited and the flow paths 61 created as a result of the baffles 21 are not always stable; rather, they are often subject to the pressure drop across the reactor and the flow rate of the gas reactants. Some dead spots still exist, and the reactants travel through the catalyst region with a wide range of resident times.

FIG. 3B shows another embodiment which uses slotted liner plates 31, instead of the baffles 21 as shown in FIG. 3A, to improve the flow characteristic in the tank reactor. A slotted liner is a thin plate containing very small perforations therethrough. The distance between adjacent slotted liner plate was about one inch. The slotted liner increased the pressure drop across the reactor and improved the distribution of gas reactants in the tank reactor. However, substantial back-mixing was experienced and the reactor deviated substantially from the desired plug flow type reaction. The flows paths 62 provided in the reactor also cross each other, and are subject to change due to changes in pressure drop across the reactor and the flow rate of the gas reactants.

As discussed above, although the baffles 21 and slotted liners 31 improved the reaction performance in the tank type reactor 10, they did not provide the desired plug flow type characteristic desired from tubular type reactors, and only a limited extent of increase in the reaction path could be obtained. Another major shortcoming associated with either the baffled or slotted liner reactor as the substantial mixing of the reactant and product streams. In catalytic reactions involving gaseous reactants, it is highly desirable to eliminate commingling of product stream with reactant stream to minimize the production of by-products.

A schematic diagram of an example of the folded path fixed bed reactor disclosed in the present invention is shown in FIG. 4. The folded path reactor 50 comprises a reactor vessel 10 which has a external dimension of 24"×12"×2", identical to that shown in FIGS. 1A and 1B. Perforated plates 12 and 13 are fixedly placed near the gas inlet 11 and gas outlet 14, respectively, in the reactor vessel 10 to improve distribution of gaseous reactants and products therethrough. The folded path 51 in the reactor vessel 10 is created with the use of a plurality of substantially rectangular partitioning plates 52 arranged in a staggered manner as shown in FIG. 4. These partitioning plates 52 provide staggered openings 53 adjacent to alternating sides of the internal walls of the reactor vessel 10 as shown in FIG. 4. Each partitioning plate has a dimension by which one side thereof is essentially identical to a corresponding side of the reactor vessel 10 to allow the pattitioning plate 52 to be firmly affixed to the inside of the reactor by a frictional force. Whereas the other side of the plate is shorter than the corresponding side of the inner wall of the reactor vessel by a predetermined length so as to form the openings 53 allowing the gaseous reactants and products to move through. It is desirable that the width of the opening is in the same order of magnitude as the spacing 54 between two partitioning plates 52.

One of the advantages of the present invention is that a tight packing can be achieved even with the presence of the partitioning plates 52, thus minimizing the occurrence of channeling, while providing the folded reaction path to increase the flow length for the reactant gas. In making a preferred embodiment of the folded reaction path reactor of the present invention, the catalyst was first loaded into the reactor vessel, without any partitioning plate, in the catalyst region 20 above the lower perforated plate 12. After the catalyst filled a pre-determined thickness, which corresponded to the designed spacing between the first pair of partitioning plates in one instance the preferred thickness was about 1.6 inches, a thin aluminum partitioning plate having a dimension of $11\frac{3}{4}$"× $1\frac{1}{2}$" was placed on top of the catalyst packing. The length of the partitioning plate 52 is almost the same but only slightly smaller than the internal width of the longer side of the reactor vessel 10 to allow the plate to be tightly but removably affixed to the reactor walls by a frictional force therebetween. The partitioning plate 52 was then inserted inside the reactor vessel such that one side thereof tightly adjoined to the side wall of the reactor, while the other side provided a half-inch opening for the gas stream to make a turn. Since the partitioning plate can be slightly bent or tilted inside the reactor vessel, the length of the partitioning plate can be slightly greater than the corresponding width of the reactor vessel to increase the frictional support.

In the above described embodiment of the present invention, the plates are held in place by the frictional force between the two edges of the plate and the inner wall of the reactor. Since most catalysts have only a limited life, it is, therefore, desirable, to have partitioning plates that are removable, as disclosed in the preferred embodiment described above. However, if necessity dictates, the present invention does not exclude the options of using permanent means, such as Welding, epoxying, screwing, etc, to securely affix the plates to

the reactor. Alternatively, t;he inner wall of the reactor vessel can be provided with a plurality of grooves to allow the partitioning plates to be securely snapped thereto.

Another approach to improve the frictional contact between the plates and the reactor is to use a "finger" design, as shown in FIGS. 5A (top view) and 5B (side view). A finger 55 is a relatively slender piece extending from the non-adjoining side of the partitioning plate so that the overall width of the plate is the same or slightly greater than the width of the corresponding inner side of the reactor vessel. The fingers 55 are designed so that they can be slightly bent (FIG. 6) to allow the partitioning plates 52 to be inserted into the reactor. One of the main purposes of using the fingers 55 is to increase the frictional contact between the partitioning plates 52 and the reactor vessel 10, thus improving the stability of the partitioning plates 52 inside the reactor. Another main purpose of the fingers 55 is to serve the function as a spacer to prevent any horizontal movement of the partitioning plates 55 and thus ensuring a stable folded path for reaction streams inside the reactor. Although the fingers 55 can be placed anywhere along the side of the plate, it is desirable that they be located at the two ends of the non-adjoining side of the partitioning plates 52 and flush with the edges, respectively, of the partitioning plates 52, as shown in FIGS. 5A and 5B By being at the end of the partitioning plate 52 and flush with the edges thereof, the fingers 55 provide additional frictional support for securing the partitioning plates 52 in place.

A fixed bed reactor as described in FIGS. 1A and 1B was constructed. A reactant stream containing oxygen, propylene, air, as shown in Table 1, was introduced into the reactor vessel 10 via the inlet 11 at a rate of 20 liters per minute. The reactor temperature was maintained at about 410°–415° C. The product stream was collected and analyzed using gas chromatography. Then results are shown in Table 1. In a separate unit, the reactor was modified by inserting partitioning plates in the procedure described above to form a fixed bed reactor containing folded reaction path. An identical reactant stream was introduced into the second reactor under identical reaction conditions. The product stream was collected and also analyzed using gas chromatography. Then results are also shown in Table 1. From Table 1, it can be seen that, with the folded path of the present invention, the yield of acrolein (defined as amount of acrolein out/amount of propylene in) was increased from 38% to 55%, and the reaction conversion (defined as the amount of propylene out/amount of propylene in) was increased from 42% to 61%. This represented an improvement of about 50% with the same quantity of catalyst, contained in the same volume and held in an enclosure of the same overall shape and dimension.

TABLE 1

Component	Without Folded Path	With Folded Path
Input Stream:		
Oxygen	18%	18%
Pxopylene	13%	13%
Nitrogen (Air)	69%	69%
Carbon Dioxide	trace	trace
Water	trace	trace
Output Stream:		
Oxygen	12.4%	7.4%
Propylene	7.6%	5.1%
Nitrogen (Air)	69%	69%
Carbon Dioxide	0.5%	2.1%

TABLE 1-continued

Component	Without Folded Path	With Folded Path
Water	5.4%	9.2%
Acrolein (desired product)	4.9%	7.1%

The locations of the partitioning plates 52, as well as the number thereof, can be conveniently adjusted according to the need and the type of reaction encountered. Furthermore, although the vertical cross-sectional area of the folded-path 51 is constant across, each spacing between two adjacent partitioning plates 52, it can be varied vertically by adjusting the spacing between the partitioning plates 52. For example, in some reactions, it may be desirable to have the partitioning plates 52 separated at a greater distance near the inlet 11 of the reactor vessel 10 than near the outlet 14 to allow for a lower linear velocity and a longer resident time during the initial stage of the reaction. This order may be reversed in other types of reactions. The present invention provides a great flexibility for the design of reaction path and locally adjustable resident times to obtain an optimum reaction condition inside the reactor vessel.

The folded path reactor disclosed in the above described embodiment may be modified to substantially increase the reaction path length/reactor length ratio. In the embodiment described in FIG. 4, the reactants travelled along the shorter edge of the partitioning plate 52 and perpendicular to the longer edge. In an alternate embodiment, the plates can be made such that it short side matches the short side of the reactor but its long side is shorter than the long side of the reactor vessel. With the alternate embodiment, the reactants travel along the longer edge of the partitioning plate 52 and perpendicular to the shorter edge, thus resulting in a substantially increased reaction path length relative to reactor length.

To further ensure that all the reactants have a uniform reaction path length, the perforated plates 12, 13 can be replaced with support plates that are perforated only at one end thereof, as shown in FIG. 7, so as is create a folded path even at the entrance and outlet portions of the catalyst region 20. The perforated portion of supporting perforated plates 12, 13 is disposed opposite the opening formed at the first and the last partitioning plate, respectively.

The foregoing description of the preferred embodiments of this invention has been presented for purposes of illustration and description. Obvious modifications or variations are possible in light of the above teaching. The embodiments were chosen and described to provide the best illustration of the principles of this invention and its practical application to thereby enable those skilled in the art to utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated. All such modifications and variations are within the scope of the present invention as determined by the appended claims when interpreted in accordance with the breadth to which they are fairly, legally, and equitably entitled.

What is claimed is:

1. A fixed bed reactor comprising:

(a) a substantially rectangular reactor vessel having an inlet, an outlet, an internal wall, and first and second inner widths; and

(b) a plurality of spaced apart partitioning plates inside said reactor vessel, said partitioning plates being spaced apart in a staggered manner so as to create a plurality of staggered openings between said partitioning plates and said reactor vessel and this a folded path for reactants traveling through said reactor.

2. The fixed bed reactor of claim 1 further comprises a catalyst region which is packed with catalyst and defined by a pair of perforated supporting plates near said inlet and outlet, respectively, of said reactor vessel.

3. The fixed bed reactor of claim 2 wherein said perforated supporting plates are perforated only at one end which is opposite to an opening formed between said vessel wall and a partitioning plate immediately adjacent said supporting plate.

4. The fixed bed reactor of claim 1 wherein said partitioning plates are fixedly but movably attached to said reactor vessel by a frictional force therebetween.

5. The fixed bed reactor of claim 1 wherein each of said partitioning plates is substantially rectangular in shape and has first and second sides, said first side of said partitioning plate plate having substantially the same length as said first inner width of said reactor vessel, and said second side of said partitioning plate being shorter than said second inner width of said reactor vessel.

6. The fixed bed reactor of claim 5 wherein each of said partitioning plates contains at least one finger extending from said first side thereof, said finger is bendable and has a dimension such that the aggregate length of said second side and said finger is substantially the same or slightly greater than that of said second inner width of said reactor vessel so as to provide an additional affixing means to secure said partitioning plates inside said reactor vessel and prevent horizontal movement of said partitioning plates.

7. The fixed bed reactor of claim 5 wherein said first inner width is substantially longer than said second inner width.

8. The fixed bed reactor of claim 5 wherein said second inner width is substantially longer than said first inner width.

9. The fixed bed reactor of claim 1 wherein said partitioning plates are spaced apart at equal spacing.

10. The fixed bed reactor of claim 1 wherein said partitioning plates are spaced apart at a greater spacing near said inlet of said reactor vessel and at a shorter spacing near said outlet of said reactor vessel.

11. The fixed bed reactor of claim 1, wherein said partitioning plates are spaced apart at a shorter spacing near said inlet of said reactor vessel and at a greater spacing near said outlet of said reactor vessel.

12. The fixed bed reactor of claim 1 wherein said partitioning plates are spaced apart at a spacing which is shorter than either said first width or said second width of said reactor vessel.

13. The fixed bed reactor of claim 1 wherein at least one half of said partitioning plates are spaced apart at a spacing which is shorter than either said first width or said second width of said reactor vessel. plate and a partitioning plate immediately adjacent thereto.

14. The fixed bed reactor of claim 1 which comprises at least three of said staggered partitioning plates.

15. The fixed bed reactor of claim 1 wherein said internal wall of said reactor vessel contains a plurality of grooves at appropriate locations allowing said partitioning plates to be snapped therein.

* * * * *

US005700434A

United States Patent [19]

Gaiser

[11] Patent Number: 5,700,434

[45] Date of Patent: Dec. 23, 1997

[54] **REACTOR FOR CATALYTICALLY PROCESSING GASEOUS FLUIDS**

[76] Inventor: Gerd Gaiser, Lange Äcker 4, D-72768 Reutlingen, Germany

[21] Appl. No.: 325,252

[22] PCT Filed: Apr. 24, 1993

[86] PCT No.: PCT/EP93/00995

§ 371 Date: Oct. 20, 1994

§ 102(e) Date: Oct. 20, 1994

[87] PCT Pub. No.: WO93/22544

PCT Pub. Date: Nov. 11, 1993

[30] **Foreign Application Priority Data**

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[51] Int. Cl.^{6} F01N 3/10

[52] U.S. Cl. 422/173; 422/171; 422/175; 422/177; 422/180; 422/198; 422/206; 422/200; 422/211; 422/222; 165/166; 165/167

[58] Field of Search 422/171, 173, 422/177, 180, 191, 198, 200, 211, 222, 175, 206; 60/299, 300, 320; 165/165–7

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Primary Examiner—Robert J. Warden

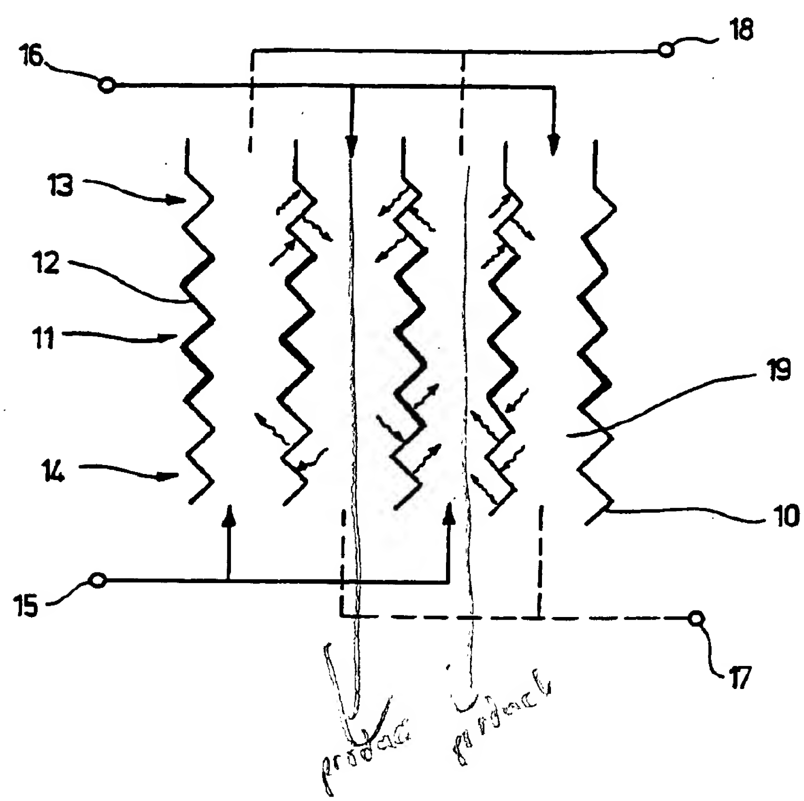
Assistant Examiner—Hien Tran

Attorney, Agent, or Firm—Anderson Kill & Olick P.C.

[57] **ABSTRACT**

A reactor for catalytically processing gaseous fluids. The invention relates to a reactor for catalytically processing gaseous fluids wherein the catalytic reaction is accompanied by a heat exchange, stationary catalysts are used, with the fluid flowing through the reactor in one direction. To this end, the fluid path-forming structures (10) are provided in the reactor housing, the structures (10) form channels (19), and the structures (10) have at least one region (11) provided with a catalyst (12), preferably coated therewith.

8 Claims, 4 Drawing Sheets



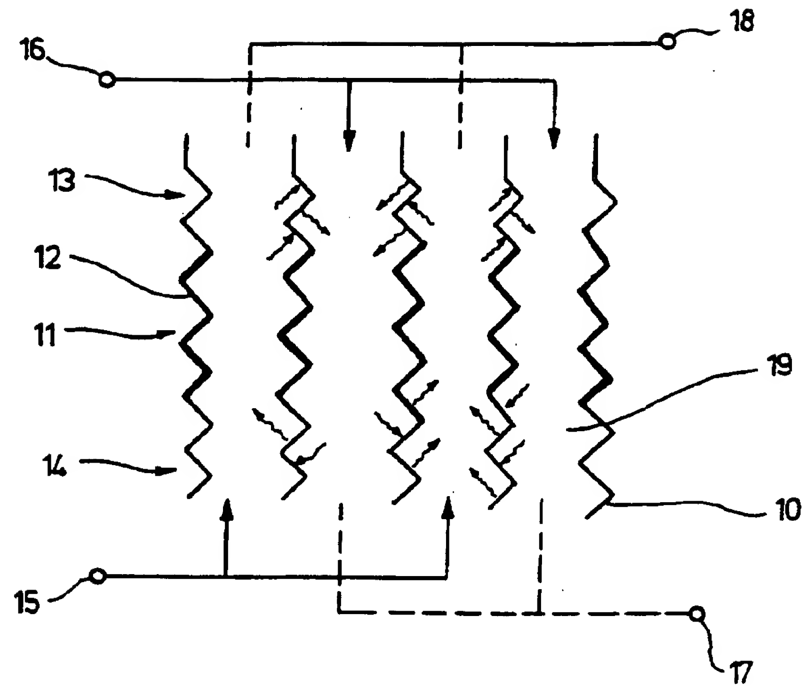


Fig. 1

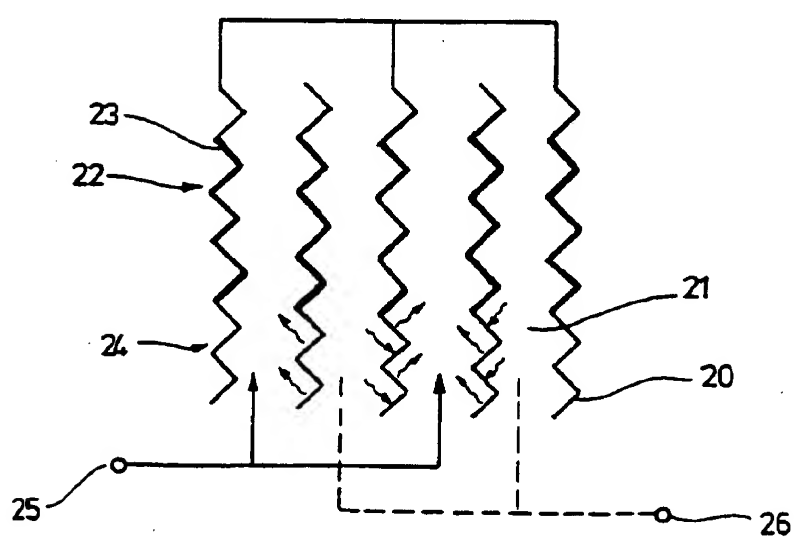


Fig. 2

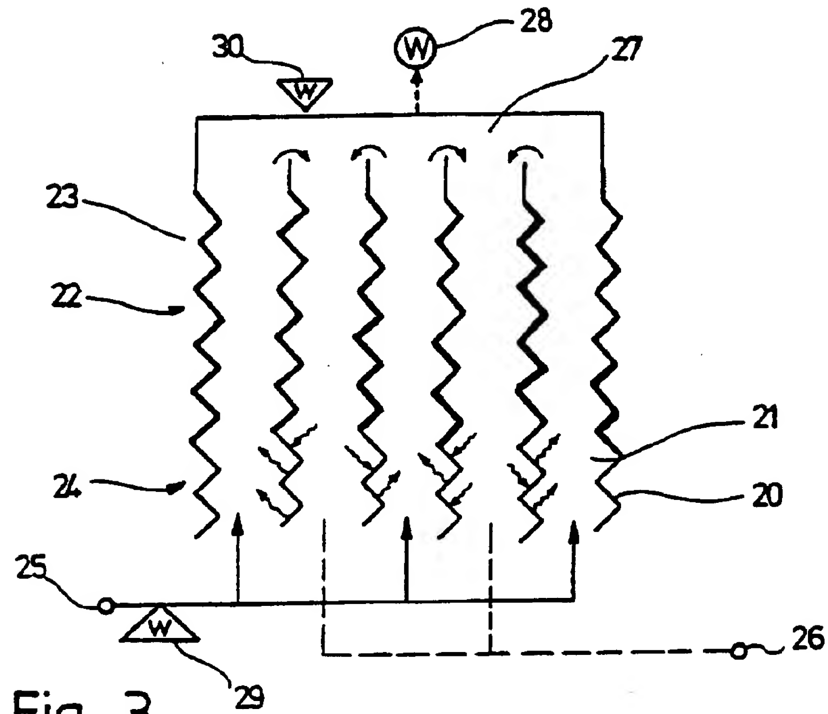


Fig. 3

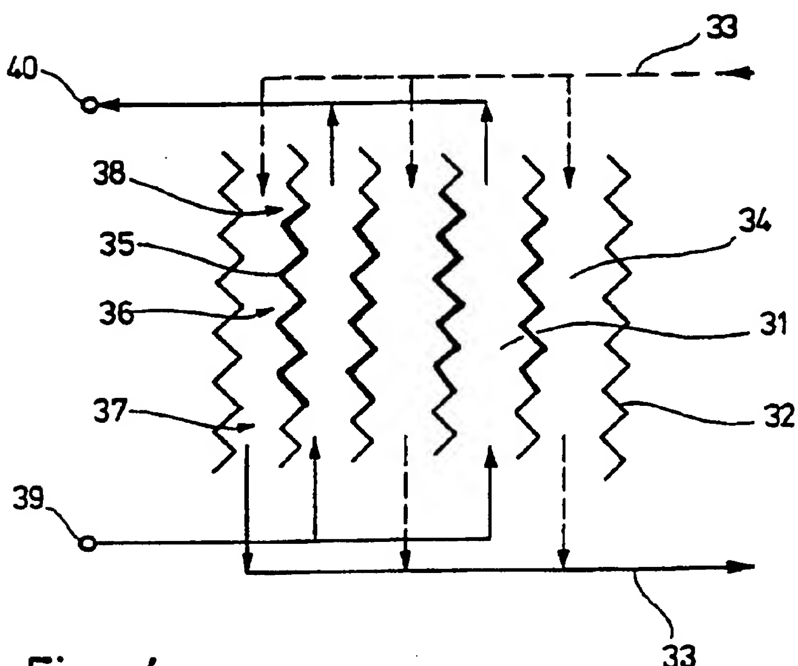


Fig. 4

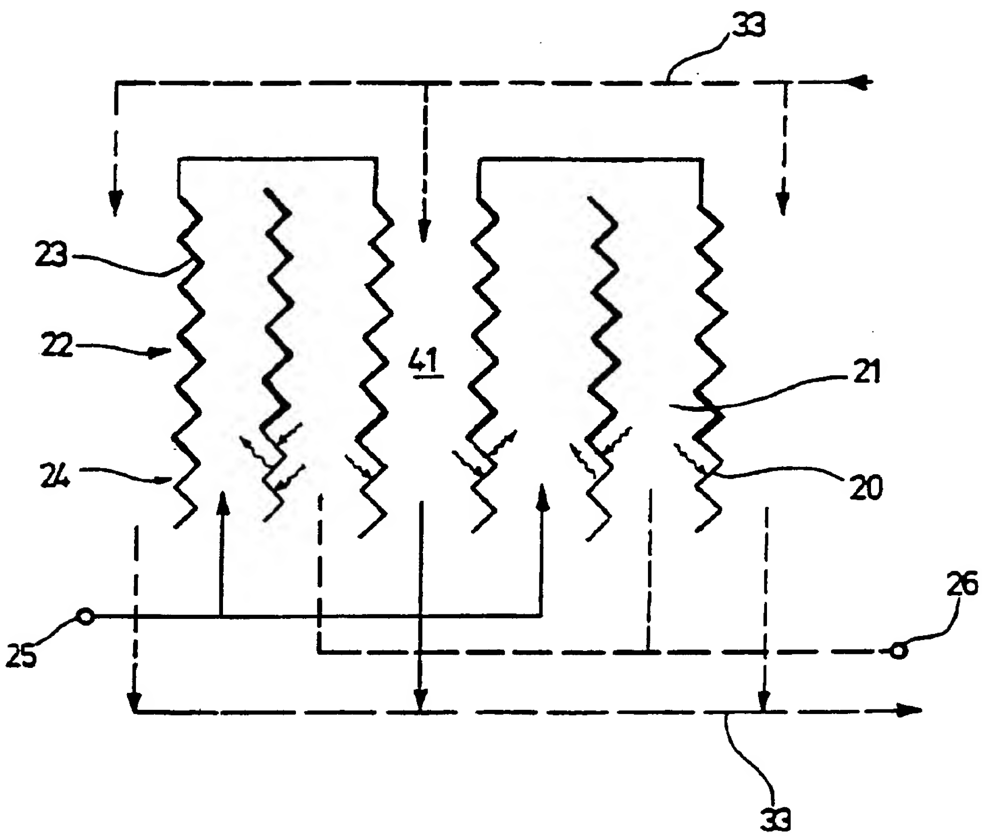


Fig. 5

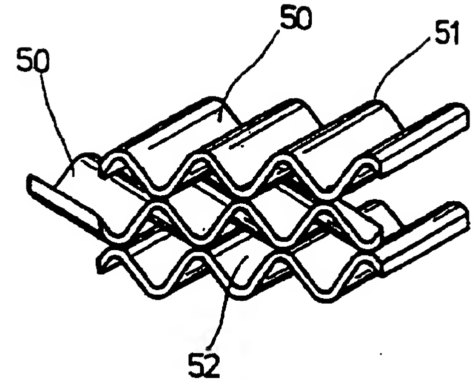


Fig. 6

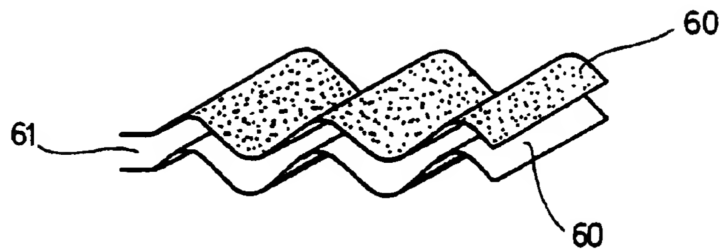


Fig. 7

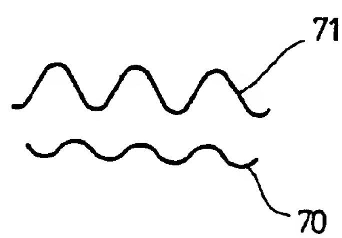


Fig. 8

REACTOR FOR CATALYTICALLY PROCESSING GASEOUS FLUIDS

The invention relates to a reactor for catalytically processing gaseous fluids in which, along with a catalytic reaction, a heat exchange takes place.

The use of catalysts for purification of outgoing air, e.g., of a solvent-containing industrial air and air used in technical synthesis, is known. The outgoing air is conducted through a reactor in which a catalyst is provided. It is typical for a catalytic oxidation that, on one side, the processed fluid is heated to a predetermined temperature so that a catalytic reaction can take place, and that, on the other hand, during a catalytic reaction, heat is released by an exothermal reaction.

As result, it is necessary to evacuate the released heat to avoid overheating and destruction of the catalyst and to supply heat, especially at the beginning of the reaction.

To this end, it is already become known to provide outgoing air reactors, in which the flow direction is periodically changed. With a high technical output, a particular drawback consists in that, during the change of the flow direction, the air, which remains in the former inlet, is discharged without being purified.

It was also suggested to conduct catalytic purification of the outgoing air in a rotatable catalyzer. At that, the stream of outgoing air due to the rotational movement of the catalyzer, flows through the catalyzer interchangeably radially or axially. However, the use of rotatable parts presents problems from the sealing point of view and, in addition, the change of the flow direction results in creation of so-called dead volume of non-purified air.

Accordingly, a particular object of the present invention is a reactor of the above-mentioned type that would enable a continuous operation without the change of the flow direction.

According to the invention, this object is achieved by so arranging the fluid path-defining elements in the reactor housing that channel-shaped structures having sectionally arranged catalytically acting regions, are formed. It has been found out that with such an arrangement, different temperature zones can be obtained at the same flow direction of the fluid. It is exactly this distribution of the temperature zones is desirable or required for catalytic purification of the outgoing gases.

It was proved to be especially advantageous when the structures have a non-flat outer surface, e.g., a corrugated outer surface, provided with a catalyst only in its middle area, so that both the beginning and end regions have no catalytic regions.

The corrugated structure of plates provides for forming flow channels between respective plates with a very high local heat and mass transfer at the plates.

This effect is advantageously used when, according to the invention, the outgoing air flows through two adjacent channels in accordance with a counterflow principle.

To this end, the fluid flow is divided so that fluid flows in the same direction only in every other channel. Thereby, it is achieved that in the first corrugated plate region, which does not have a catalyst, the heat from air, which has already passed the catalyst and which was heated by an exothermal reaction, is transferred to this plate region, and the air, which has yet to be subjected to the catalytic treatment and which flows in the adjacent channel, is preheated due to heat transfer. In the second corrugated plate region, which likewise does not have a catalyst, the same heat transfer takes place, but in the opposite direction.

In accordance with a further development of the invention, it is contemplated that fluid flows through two respective, connected with each other, adjacent channels so that the reaction heat, which is generated in a fluid stream, can be transferred to the same stream for preheating.

Instead of being sealed, the channels can end in a common collecting channel, with branching therefrom into respective adjacent channels. Such flow configuration results in that the fluid is compulsorily delivered to the reactor at the same pressure.

In an advantageous embodiment of the invention, it is contemplated to provide in the collecting channel a device for extracting and/or addition of heat. Thereby, the thermal content can alternatively be regulated in accordance with the course of the reaction, strong exothermal or less than strong exothermal.

By an appropriate shaping of the plate outer surface, a very high heat and mass transfer between the fluid and the wall is achieved, as well as a predetermined uniform dwell time and a homogeneous mixing in the fluid phase.

The shape of the plate outer surface, in view of the very high heat transfer, is based upon the fact that, e.g. during the catalytic purification of solvent-containing outgoing air, the concentration of harmful material is low and is further reduced by catalysis-generated heat. As a result, a small temperature difference exists between the incoming air and the outgoing air. This leads to a relatively little heating of the air during the reaction and, therefore, to a small temperature difference between the purified air after the reaction and the non-purified air before the reaction.

In order to bring the air, which is admitted into the reactor, to a reaction temperature, the relatively small quantity of heat, which is contained in the outgoing air at small concentration of solvents, should be transferred to the incoming air as completely as possible.

In accordance with the invention, with the above-described autothermal reactor types, the use of strong exothermal or strong endothermal reactions, a uniform heat addition or heat extraction is necessary because, otherwise, the catalyst is destroyed or, when endothermal reaction takes place, quenching of the reaction takes place. Further, according to the invention, additional heating and/or cooling channels are contemplated in addition to the already described fluid path-defining structures. These are advantageously provided between two respective fluid paths.

The constructional forms are adapted to particular requirements, e.g., for autothermal operation, the outer surfaces of the heat receiving and heat releasing zones can, for a different heat and mass transfer, be layed out as reaction zone.

According to a further advantageous embodiment of the invention, it is contemplated to displace the described plates relative to each other so that adjacent plates form contacting each other opposite wave-shaped structures. The wave-shaped structures can have different height dimensions and can be spaced from each other a different distance.

It can also be very advantageous to use plates having opposite orientation so that the plates support each other. With this construction, the best results are achieved.

Further advantageous solutions are apparent from the subclaims.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be explained in detail with reference to several embodiment examples and respective accompanying drawings. It is shown in:

FIG. 1 a single-path reactor;

FIG. 2 a double-path reactor;

FIG. 3 a double-path reactor with a collecting channel;

FIG. 4 a reactor with additional heating and cooling channels;

FIG. 5 a further reactor with heating and cooling channels;

FIG. 6 a variant of a plate arrangement;

FIG. 7 a further variant of the plate arrangement; and

FIG. 8 a variant of a plate construction.

FIG. 1 shows a reactor for catalytic processing of gaseous fluids. For the sake of clarity, here and in further figures, the reaction housing is not shown.

A plurality of plates **10**, which have a corrugated structure, are arranged parallel to each other and define channels **19**. The plates **10** have a region **11** in which the opposite sides of plates are provided with a catalyst **12**, e.g., are coated. In addition, the plates **10** have regions **13** and **14**, which are not provided with the catalyst, that is, they do not have any coating. For delivering fluid, an inlet **15** and an inlet **16** and, for carrying away the products of the reaction, an outlet **17** and an outlet **18** are provided.

The reactor functions as follows:

The fluid, which is delivered through the inlet **15**, is so divided that it flows in the same direction only through every other channel **19**. The fluid, which is delivered through the inlet **16**, likewise flows through every other channel **19**. Thus, a counterflow is provided in two adjacent channels **19**. When the fluid passes through the region **11**, provided, e.g., covered with a catalyst **12**, a catalytic reaction takes place. During this reaction, the heat is released which is transferred to the fluid. When the fluid then passes through the region **13**, the heat is transferred to the plates **10**. When a non-processed and, thus, cold fluid flows in the adjacent channel **19**, it takes up the heat. So pre-heated fluid enters the reaction zone of its channel **19** and there is catalytically processed. Due to the exothermal reaction, the fluid is heated further and then gives up the heat to the plates **10** in the region **14**.

Because of the alternate flow of fluid in channels **19**, an autothermal process takes place. Thus, each flow channel has regions with different functions: in the first portion, the fluid is heated up, the fluid reacts in a middle portion and in a third portion, gives up heat to a fluid in the adjacent channels. Thereby, it is insured that the fluid is preheated to a respective pre-reaction temperature. At the first activation of the reactor, an additional, single time, preheating of the fluid may be required.

The heat flow in the plates can be changed and thereby influenced by selection of the plate thickness, plate material, and the configuration of the outer surface of a plate.

Also, it is possible in a manner not shown here, to so equip, e.g., cover the plates **10** with the catalyst **12**, that regions with different temperatures and, therefore, different functions, (heating, catalytic reaction, cooling) are provided. When, e.g., a certain time period is required for heating the fluid, then the first region is cooler, and in the last region, which is also covered with the catalyst, no further heating takes places, as due to the already taken place catalytic reaction, no heat transformation takes place in the purified fluid.

FIG. 2 shows another embodiment of the reactor. Here, likewise several plates **20**, having corrugated structure, are arranged parallel to each other and form channels **21**. The plates **20** have a region **22**, with the opposite sides of the plates **20** being provided, e.g., coated with the catalyst **23**, and a region **24**, with no coating. Two respective non-adjacent plates **20** are connected with each other so that two channels **24** surround a coherent bent reaction space. The reactor has an inlet **25** for the fluid and an outlet **26** for the products.

The reactor functions as follows:

The fluid is delivered to the reactor through the inlet **25** and is divided so that it flows in every other channel **21**. In the region **22** of the plates **20**, a catalytic reaction takes place. This reaction takes place during flow of fluid in both directions, up and down. The fluid, which was heated by the exothermal reaction, gives up heat to the plates **20** in the region **24** when flowing downward. The heat, which was released in the region **24** is transferred to the upwardly flowing fluid in the adjacent channel **21**, whereby this fluid is pre-heated to a desired pre-reaction temperature.

FIG. 3 shows a further embodiment of the reactor. This reactor, contrary to that shown in FIG. 2, instead of the connection of two non-adjacent plates **20**, has a collecting channel **27**. The channels **21** open into this collection channel, whereby the fluid can flow back through different channels.

In the embodiment shown here, an offtake **28** is provided in the collecting channel **27** for conducting heat energy away. Thereby, it is possible to carry away an excessive heat energy generated during strong exothermal catalytic reaction. However, the heat carrying away is effected so that a sufficiently large amount of the heat energy remains for heating of the plates **20** in the region **24**.

In addition, two external pre-heating devices **29** and **30** are provided. These pre-heating devices are necessary for an initial activation of the reactor for pre-heating the fluid to the required reaction temperature. To this end, alternatively, the pre-heating device **29** is provided at the fluid inlet, and the pre-heating device **30** is provided in the collecting channel **27**.

The above-described embodiment examples are layed out for an autothermal operation.

FIG. 4 shows an embodiment of a reactor which is used at both strong exothermal and strong endothermal reactions. Here, channels **34**, which are formed by pairs of respective plates **32** defining a reaction space **31**, form part of a cooling or heating circuit **33**. The plates **32** have a region **36**, coated with a catalyst **35**, and lower and upper regions **37** and **38**, which are not coated.

The plates **32** are coated with the catalyst only on the side thereof facing the reaction path.

The reactor functions as follows:

The fluid is delivered to the reactor through the inlet **39** and is conducted into the reaction space **31**. There, the fluid is subjected to the already described catalytic reaction in the region **36** and is carried away through the outlet **40** dependent upon whether strong exothermal or strong endothermal catalysis takes place, cooling or heating medium is conducted through the channels **34**. This results in heat being supplied into or carried away from the reaction space **31**. Thereby, the catalytic reaction is balanced. The regions **37** and **38** form, in this embodiment, already mentioned heating or cooling zones for the fluid.

In another, not shown, embodiment example, the regions **37** and **38**, which are not provided, e.g., are not coated with a catalyst, can be dispensed with, so that the plates **32** are coated with the catalyst **35** along their entire length. The cooling or heating then provided by the medium that flows through the channels **34**.

Another embodiment of the reactor is shown in FIG. 5. Here, the construction shown in FIG. 2 is combined with a cooling or heating circuit 33. Thus, it is possible to use a longest possible reaction path and thereby to extract additional heat or to add additional heat, if needed.

FIGS. 6–8 show different plate arrangements which do not depend on general construction of the reactor.

FIG. 6 shows a perspective view of a plate arrangement.

It is apparent that the plate 50 are alternatively arranged at an angle one above the other. The plates 50 are supported here on their bulging 51 defining the corrugated structure.

Such an optimal support simultaneously provides for good stability, even with very thin walls. Because the thin walls insure good heat conductivity, an optimal construction is thereby obtained.

The plates 50 form channels 52. The channel 52, because of the bulgings 51, do not extend at the same level. These obstructions lead to an increased turbulence in the fluid stream and/or in the stream of cooling or heating medium and, as a result, in a better performance of the whole apparatus.

As a displacement angle, an angle between 0° and 90° can be used.

Further, as FIG. 7 shows, it is possible to arrange the corrugated structures so that they are located one beneath the other. The plates 60 are so arranged that they form a through channel 61. Between the plates, there are provided additional supports (not shown).

As further shown in FIG. 8, it is advantageous when the plates 70 and 71 have a different shape and differ from each other in height and form corrugated structures with a different spacing between corrugation.

The invention is not limited to the shown embodiments, but rather relates to all catalyst-containing reactors, the heating and/or cooling zones of which can be associated with the processed fluid.

It is also within the scope of the invention, when the shown catalyst regions 11, 22, 36 are not continuously provided with a catalyst, coated therewith, but also have catalyst-free regions. Thereby, a more precise heating during conducting the entire process is possible.

Generally, it is possible to provide the fluid paths with a catalyst in any arbitrary manner. For example, the coating of the walls with a catalyst mass can be eliminated and instead, a catalyst-covered structure, e.g., a grid, or a catalyst in bulk can be provided in the fluid path.

What is claimed is:

1. A reactor for catalytically processing gaseous fluids, comprising:

a plurality of fluid path-forming elements spaced from each other to form a plurality of alternatively arranged first channel means and second channel means through which fluid flows in opposite direction, each of said first and second channel means having inlet and outlet regions, wherein at least the inlets of said first channel means and at least the outlets of the second channel means are without catalyst, and wherein each of said first channel means and said second channel means have at least one region other than the inlet and outlet region thereof provided with a catalyst, with the inlet regions of the first channel means and the outlet regions of the second channel means providing for heat exchange between adjacent first and second channel means; and

means for feeding fluid to inlet regions of said first channel means and for discharging fluid from the outlet regions of said second channel means.

2. A reactor according to claim 1, wherein the fluid-path forming elements are formed as plates having non-flat surfaces.

3. A reactor according to claim 1, wherein the feeding and discharging means includes a fluid inlet, and wherein the reactor further comprises pre-heating means arranged in the fluid inlet.

4. A reactor according to claim 1, wherein the fluid path forming elements are formed as plates extending parallel to each other, and wherein the first and second channel means form part of at least one of a cooling circuit and a heating circuit.

5. A reactor according to claim 1, wherein the fluid path-forming elements are formed as plates, and wherein the region provided with a catalyst is located on one side of the plate.

6. A reactor according to claim 2, wherein the plates have a wave structure.

7. A reactor according to claim 6, wherein wave crests of the adjacent plates project in opposite directions so that the plates support each other and form the plurality of first and second channel means.

8. A reactor according to claim 6, wherein the wave structure is formed as a corrugated structure having different dimensions in at least one of height and spacing.

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